KARIBA

TEXAS ENGINEERS LIBRARY
COLLEGE STATION, TEXAS
NOV 1 / 1961

Consulting Electrical and Mechanical Engineers: Messrs. Merz and McLellan

and AEI

Six 100-MW generators for Stage One of the massive hydro-electric project at Kariba, on the Zambesi river, are being supplied by AEI. They are the largest hydro-electric generators in the entire continent of Africa.

AEI

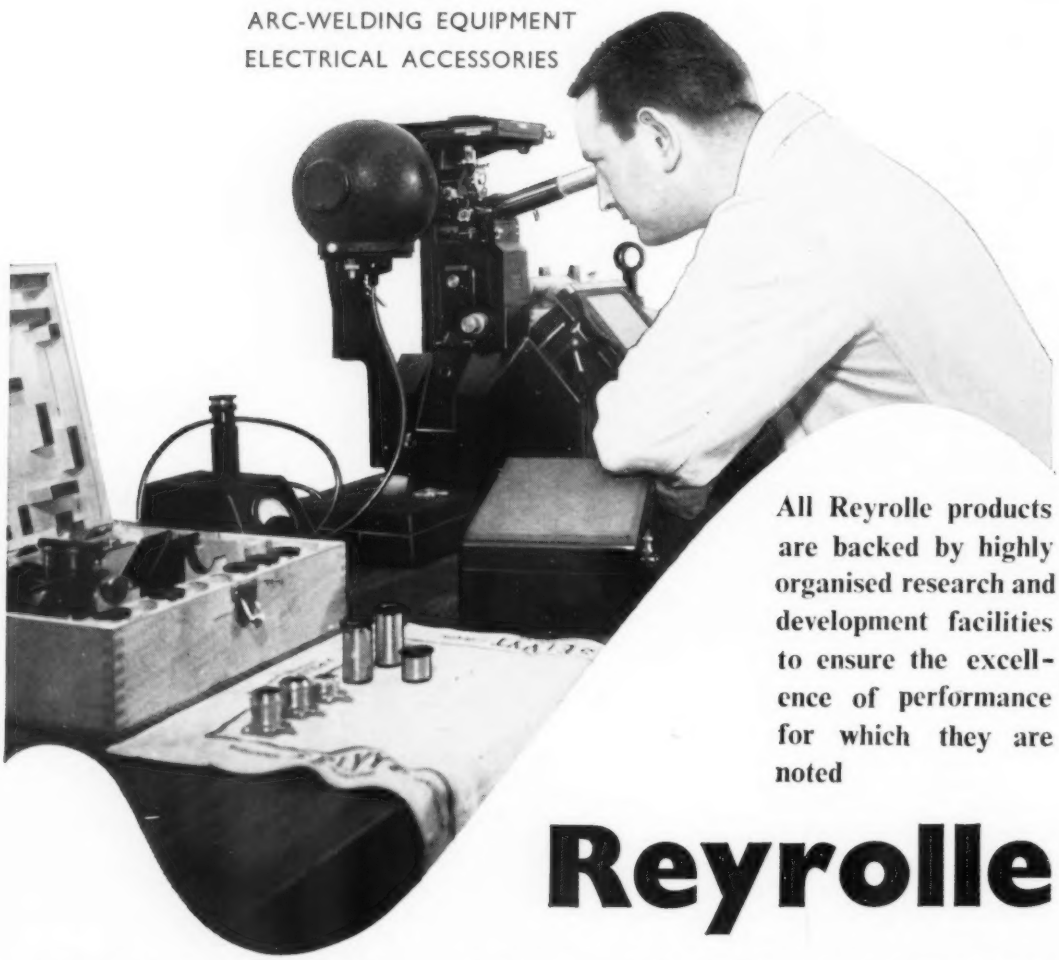
Associated Electrical Industries Limited
Heavy Plant Division
RUGBY, ENGLAND

A5552

RESEARCH FOR PERFECTION

Specialists in the manufacture of :

AIR-BLAST SWITCHGEAR
SMALL-OIL-VOLUME SWITCHGEAR
METALCLAD SWITCHGEAR
AIR-BREAK SWITCHGEAR
FLAMEPROOF SWITCHGEAR
SWITCH-AND-FUSE GEAR
CONTROL EQUIPMENT
PROTECTIVE GEAR
A.C. COMMUTATOR MOTORS
ARC-WELDING EQUIPMENT
ELECTRICAL ACCESSORIES



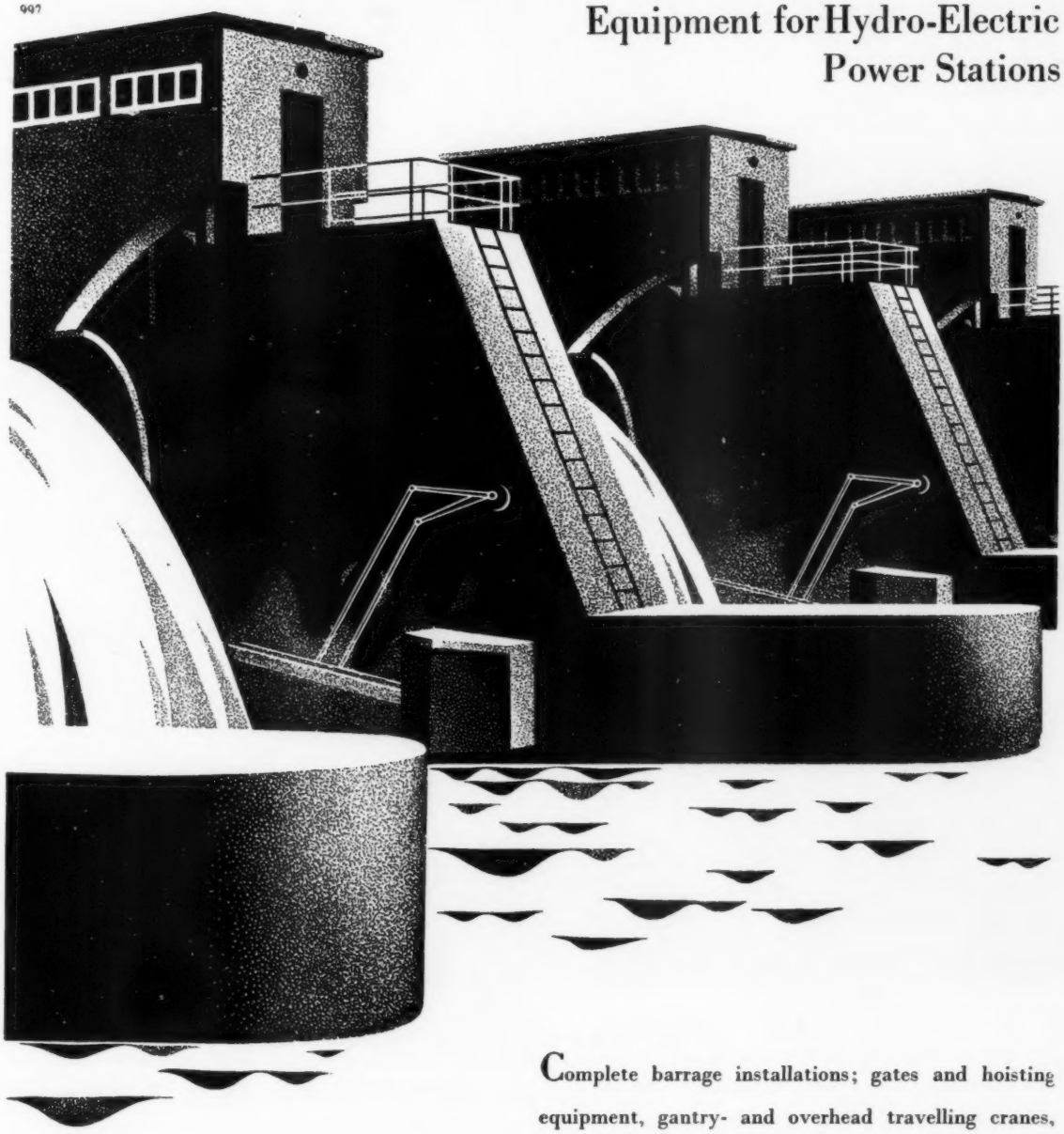
All Reyrolle products are backed by highly organised research and development facilities to ensure the excellence of performance for which they are noted

Reyrolle

A. REYROLLE & CO. LIMITED HEBBURN - COUNTY DURHAM - ENGLAND

997

Equipment for Hydro-Electric Power Stations

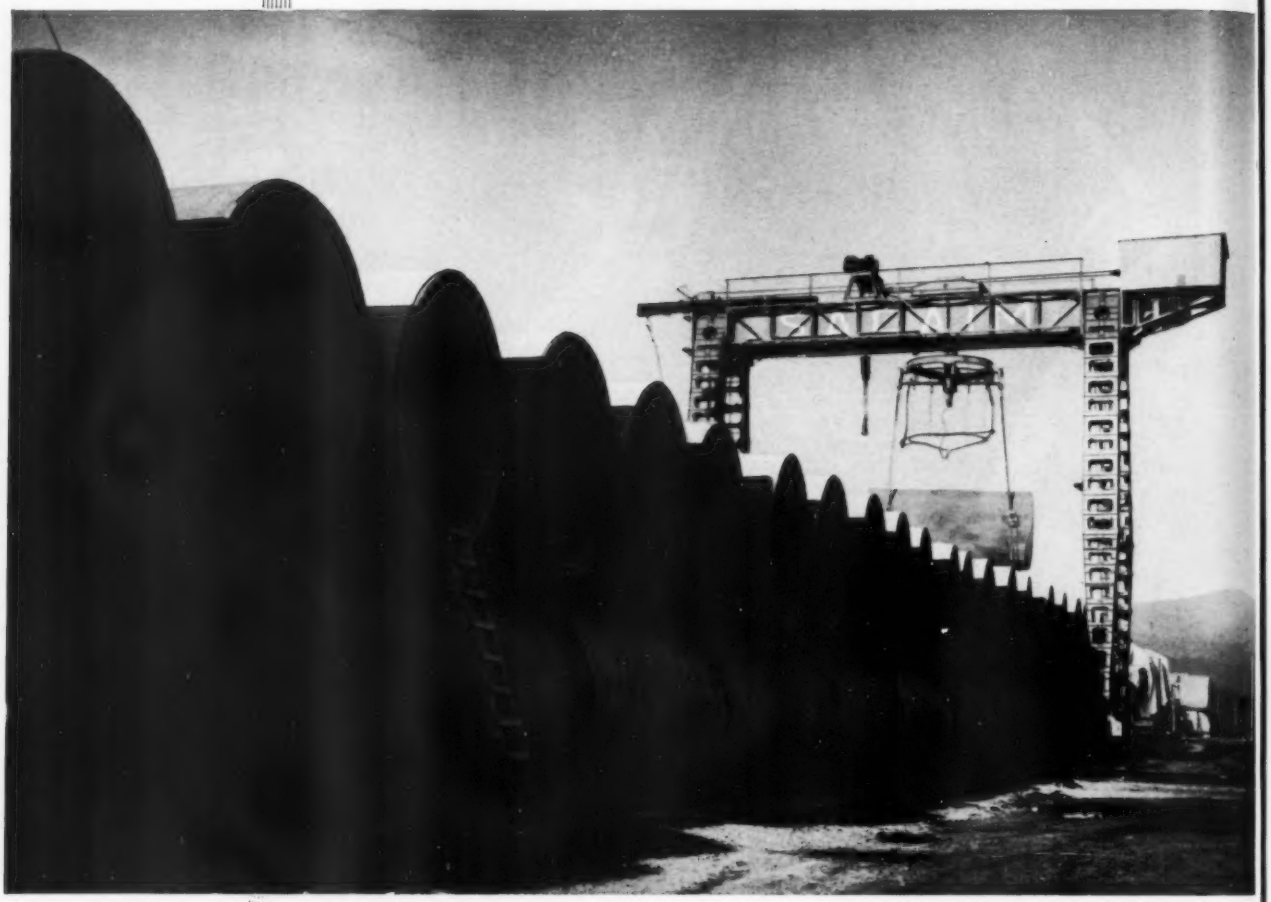


Complete barrage installations; gates and hoisting equipment, gantry- and overhead travelling cranes, trash screen cleaning machinery; sluice gates; control valves for high pressure conduits; automatic safety organs for pipe lines; discharge regulating valves, rotary valves with rotary-piston servomotors, needle valves, butterfly valves, high pressure fittings, piping systems for oil and cooling water plant; funicular and aerial cableways for passenger and goods transport; building machinery for dam-building work.

DE ROLL

Louis de Roll, Ironworks Ltd.
Gerlafingen, (Switzerland)

Prestressed reinforced concrete penstocks of any diameter and pressure



Main penstocks of prestressed reinforced concrete (diameter 6 ft. 7 ins., operating at 440 lb. per sq. in.) made for the Maè-Piave Hydro-Electric station of
S.A.D.E. - SOC. ADRIATICA DI ELETTRICITA'

SACAIM

Soc. p. Az. Cementi Armati Ing. Mantelli

VENICE (ITALY) - Accademia 979/A - Telephone 85.060

Boving robust design ensures

enduring efficiency

The illustration shows Boving Patent Rotary Valves in course of construction. These valves are used in high-head installations and are particularly notable for their —

SIMPLICITY · LOW HEAD LOSS · ROBUST DESIGN

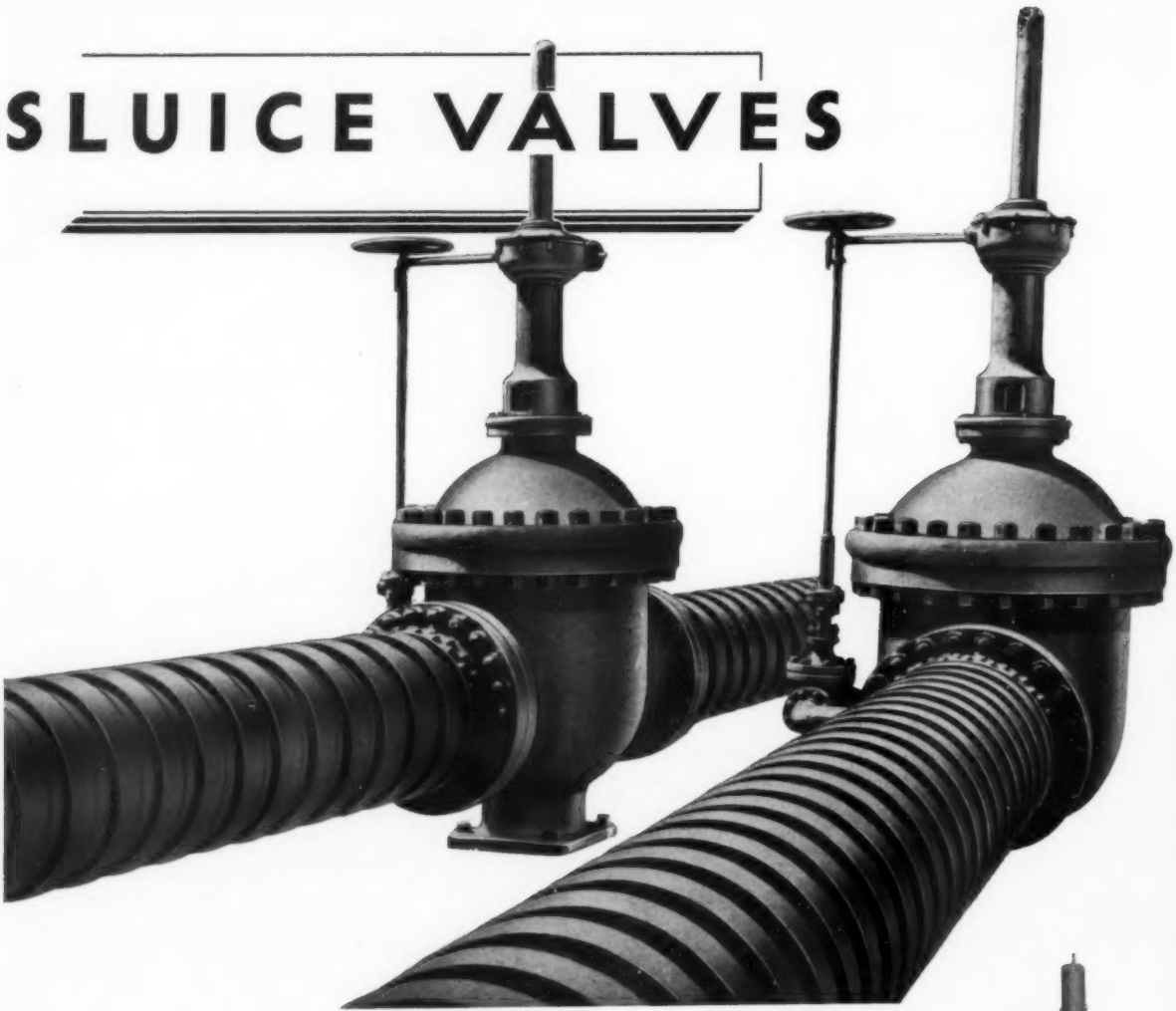
Constant research into design and production methods, backed by the latest advances in technology, maintain Boving Quality at the highest standard. Simplicity and quality finish achieves increased reliability and reduces costly outages.

Boving
& CO LIMITED

VILLIERS HOUSE
41-47 STRAND LONDON WC2

P.6179

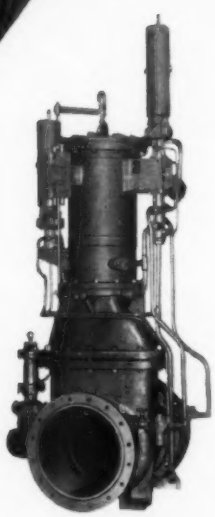
SLUICE VALVES



for Pipelines..

Such equipment is a Glenfield specialty, and can be supplied in various designs to suit a wide range of operating conditions, in hand, hydraulically and electrically operated forms.

Illustrated are examples of high-pressure round-bodied hand-actuated units, and of oval-bodied medium-pressure hydraulically-operated valves.



Glenfield

GLENFIELD & KENNEDY LIMITED KILMARNOCK

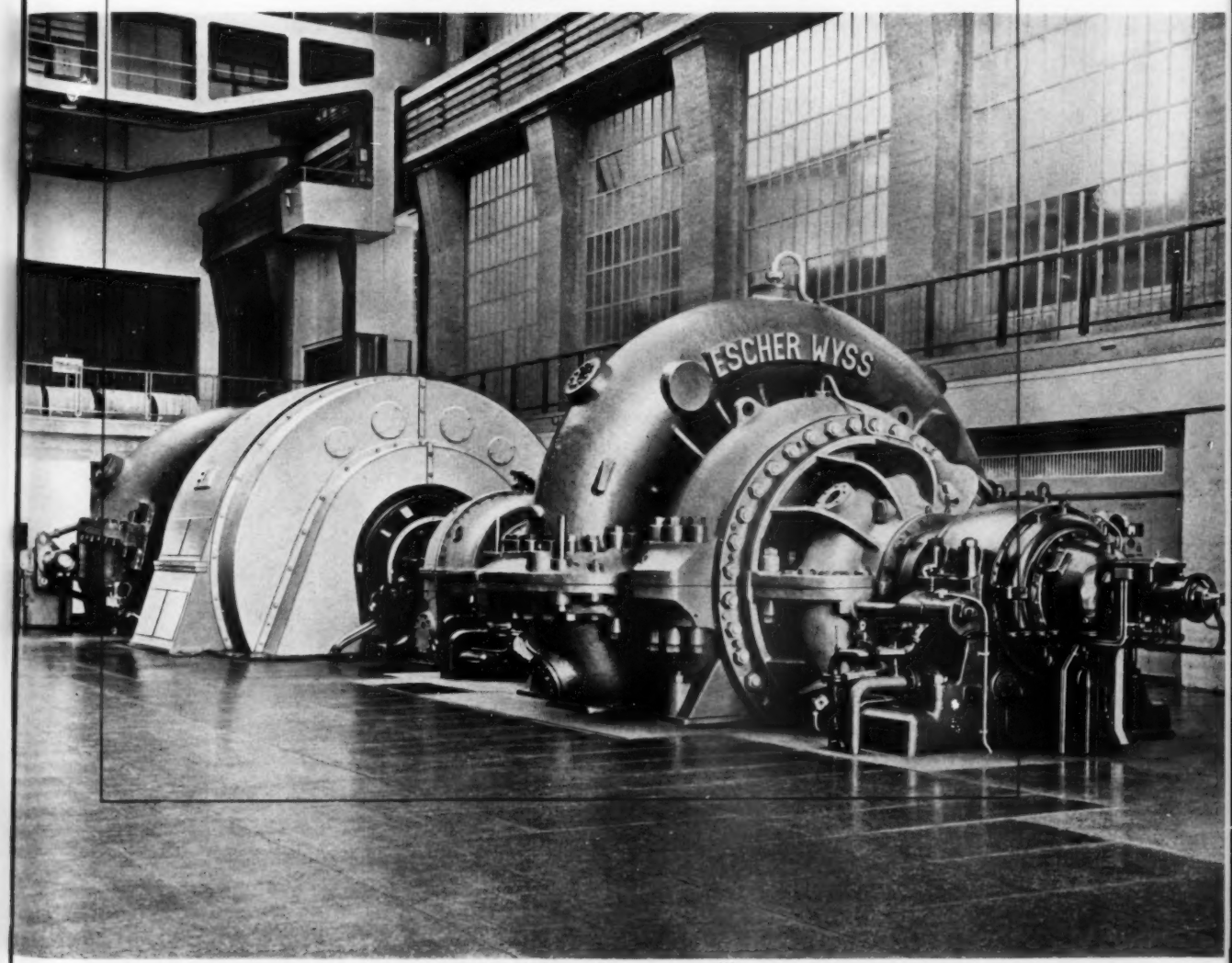
KILMARNOCK · SCOTLAND

ESCHER WYSS

23 Storage Pumps with a total input exceeding 1000000 HP

Escher Wyss manufacture the complete hydraulic equipment for Storage Power Plant
These installations are becoming of increasing importance due to the advantages they offer in dealing with peak load of thermal power plant, whilst utilizing the surplus energy of the latter during periods of reduced current consumption

Our European works are at present manufacturing 23 Storage Pumps with inputs totalling over 1000000 HP for installations in Germany, Italy, Luxembourg, the Near East and Switzerland. They include five 93000 HP units for Vianden/Luxembourg and two 91700 HP units for Villa Gargnano/Italy



Storage Power Plant at Limberg/Austria for which we supplied 2 Francis Turbines each developing 77000 HP under 364 metres and 2 Storage Pumps for heads of 320–420 metres with inputs of 85000 HP per unit

Escher Wyss Ltd., Zurich/Switzerland

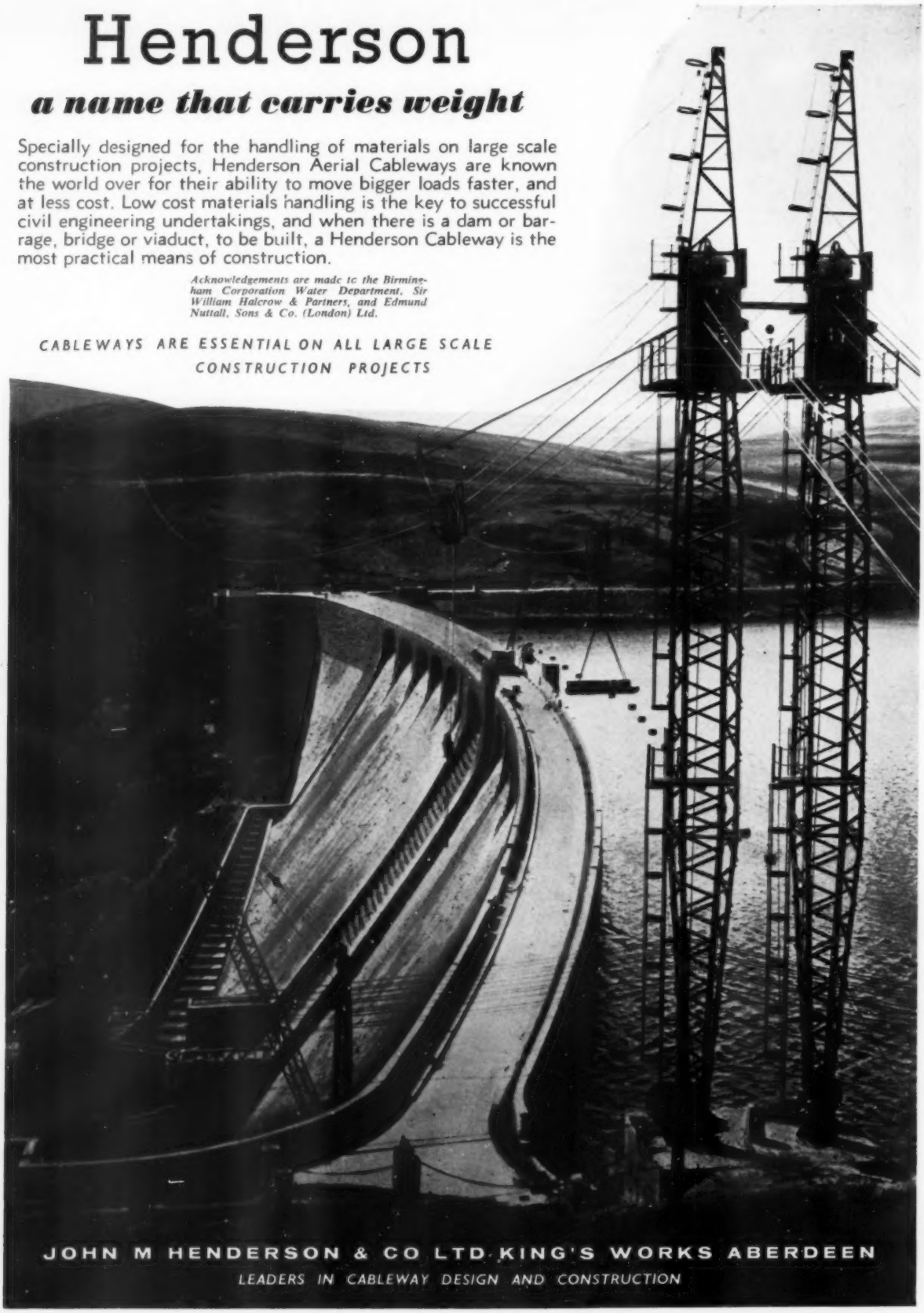
Henderson

a name that carries weight

Specially designed for the handling of materials on large scale construction projects, Henderson Aerial Cableways are known the world over for their ability to move bigger loads faster, and at less cost. Low cost materials handling is the key to successful civil engineering undertakings, and when there is a dam or barrage, bridge or viaduct, to be built, a Henderson Cableway is the most practical means of construction.

Acknowledgements are made to the Birmingham Corporation Water Department, Sir William Halcrow & Partners, and Edmund Nuttall, Sons & Co. (London) Ltd.

CABLEWAYS ARE ESSENTIAL ON ALL LARGE SCALE CONSTRUCTION PROJECTS

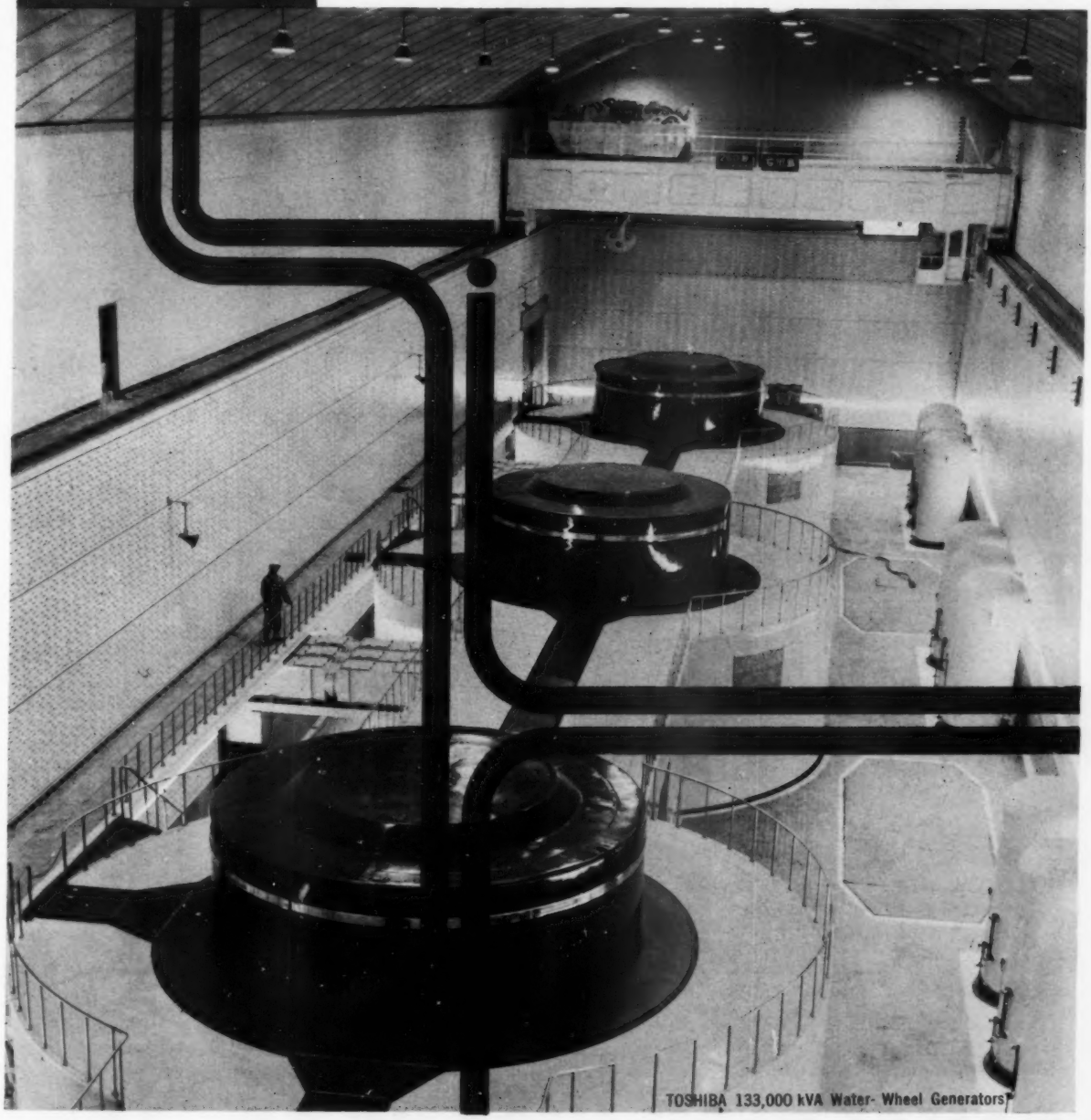


JOHN M HENDERSON & CO LTD KING'S WORKS ABERDEEN

LEADERS IN CABLEWAY DESIGN AND CONSTRUCTION

Toshiba
QUALITY SINCE 1875

Contributing to Your Better Living !



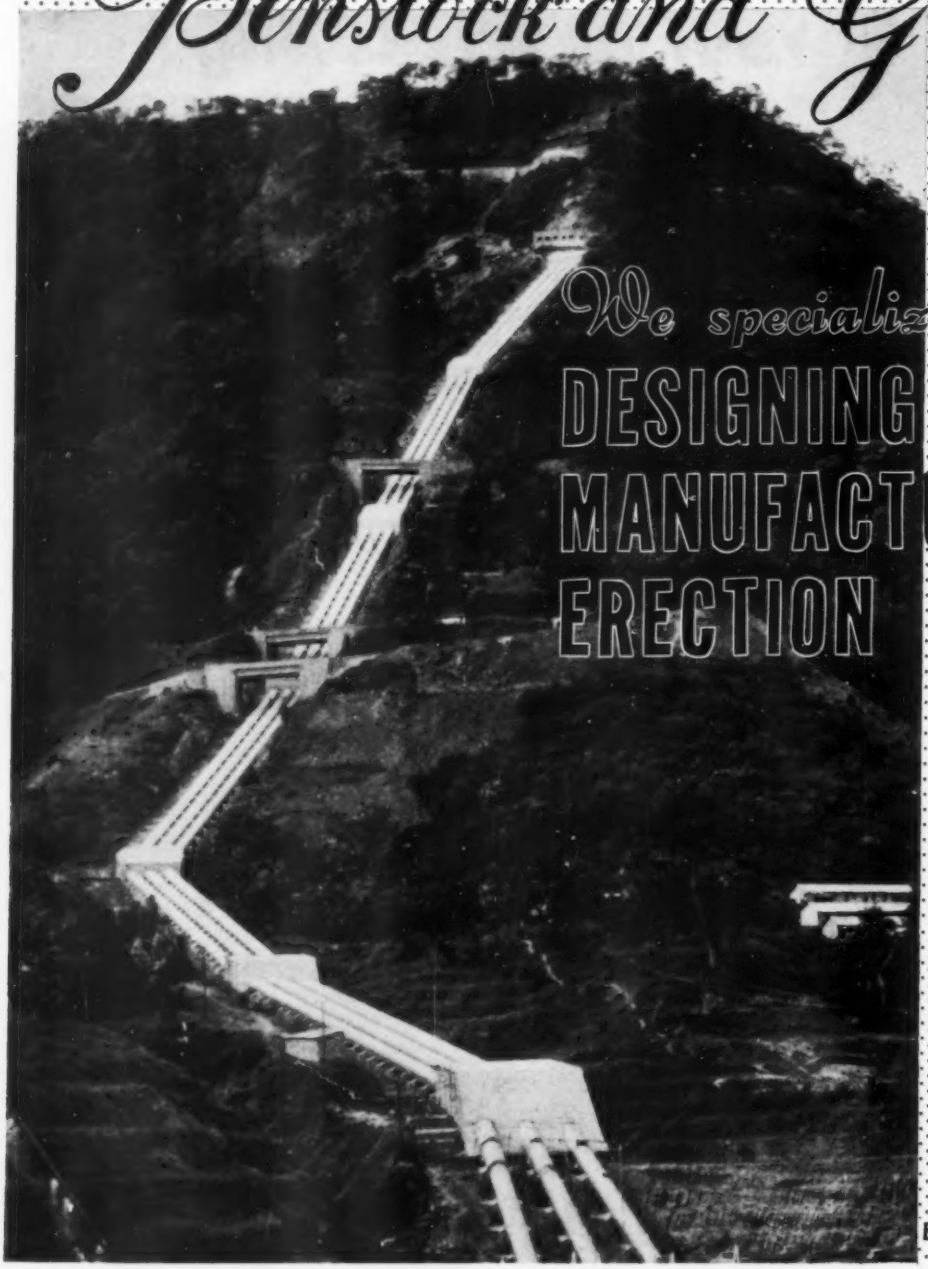
TOSHIBA 133,000 kVA Water- Wheel Generators

Boosting Japan's electrical power capacity for her busy industries is the mission of these huge generators. This autumn they'll each begin generating 133,000 kVA — enough power to bring progress to an area of twenty million people, they were built by Toshiba, where 85 years' accumulated experience is daily translated into thousands of quality electrical products for home and industry throughout the world.

TOKYO SHIBAURA ELECTRIC CO., LTD.

Tokyo, Japan Cable: TOSHIBA TOKYO

Penstock and Gate



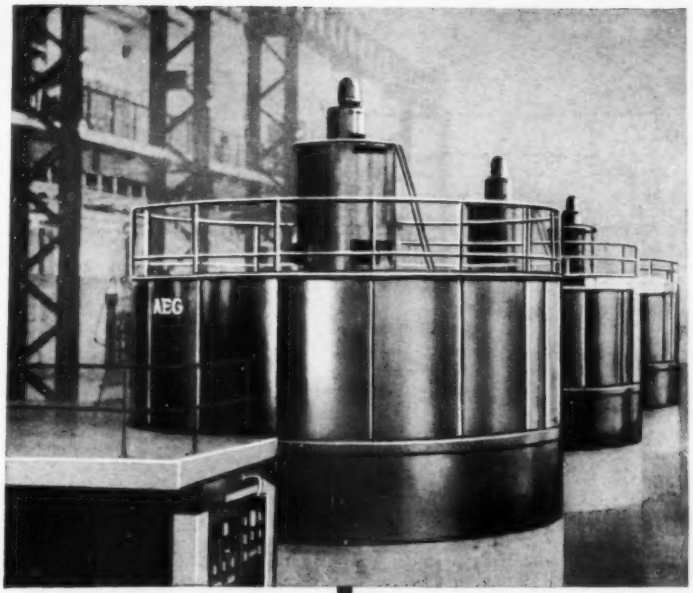
We specialize in . . .

DESIGNING
MANUFACTURING
ERECTION

Established: 1904

SAKAI IRON WORKS CO., LTD.

HEAD OFFICE: NISHI, 6-CHOME, TSUMORI-CHO, NISHINARI-KU, OSAKA, JAPAN CABLE ADDRESS: "SAKATETSU OSAKA"
TOKYO OFFICE: NIHONBASHI-GOFUKUBASHI, CHUO-KU, TOKYO, JAPAN CABLE ADDRESS: "SAKATETSU TOKYO"

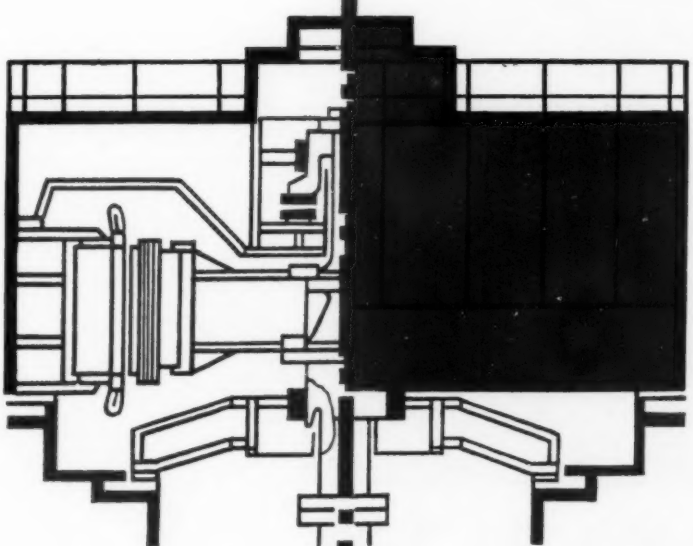


Three 41 200 kVA generators at Periyar Hydro-Electric Station, India

AEG

In all parts of the world where natural resources are harnessed to provide the increasing demands for electrical energy

AEG waterwheel alternators



have proved their unfailing reliability.

More than sixty years experience, skilled craftsmen, specialized research and production methods, ensure first-class technical design and quality of the equipment.

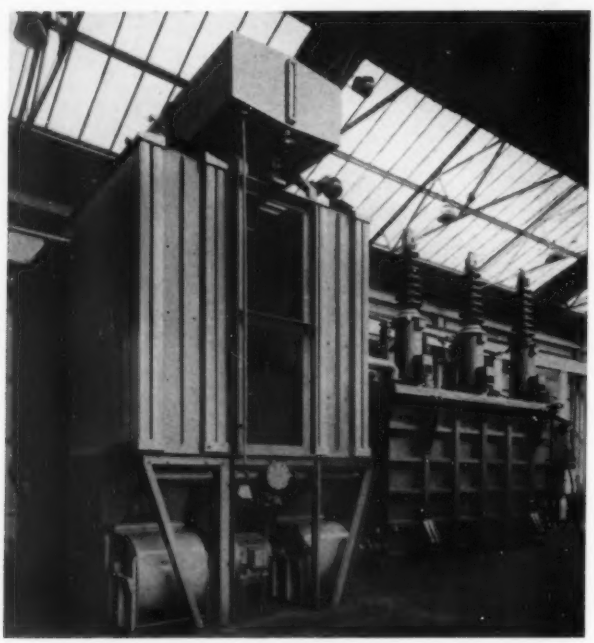
8826e

ALLGEMEINE ELEKTRICITÄTS-GESELLSCHAFT

Berlin (West) EXPORT DEPARTMENT Frankfurt (Main)

transformers, installed throughout the world

YORKSHIRE TRANSFORMERS

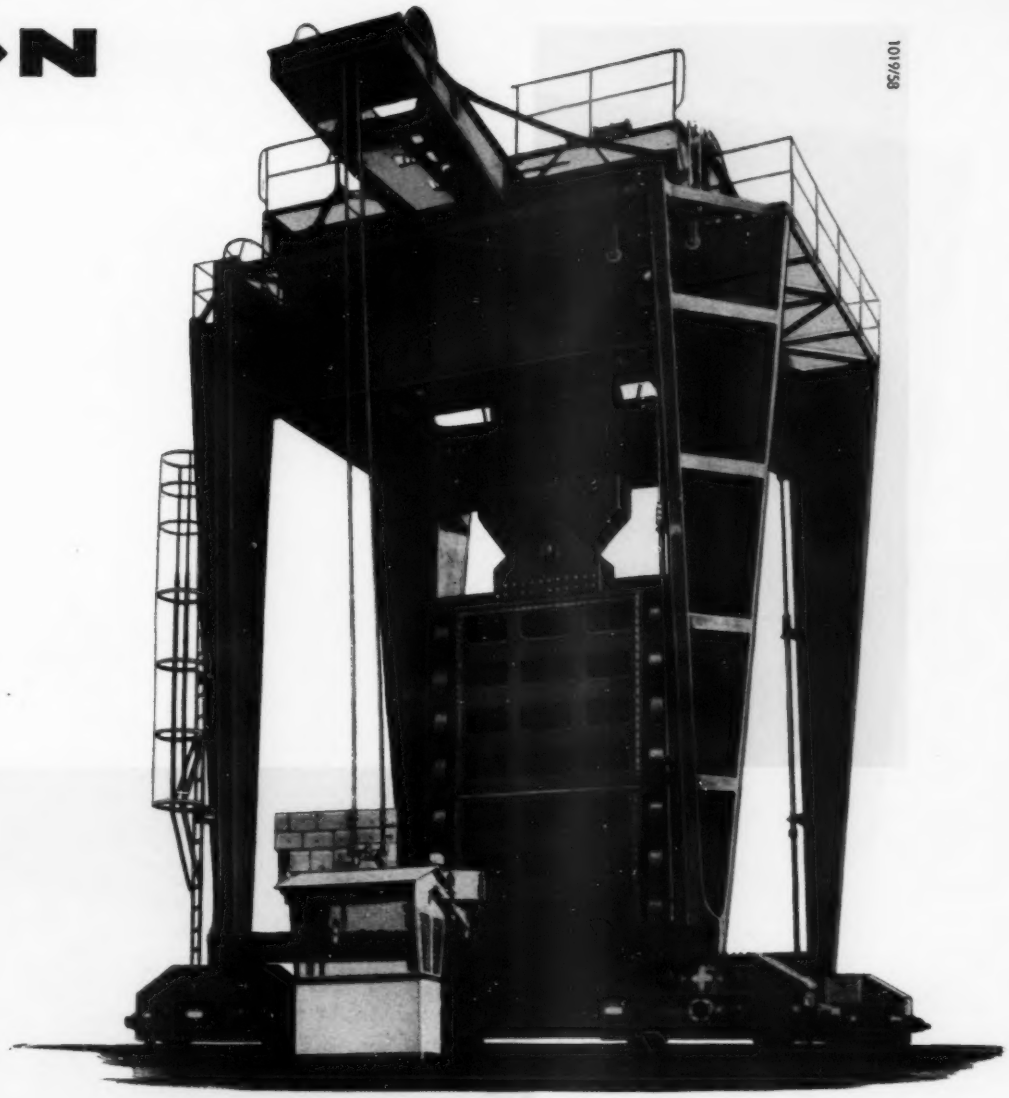


132 kV

YORKSHIRE

YORKSHIRE ELECTRIC TRANSFORMER CO. LTD.,
THORNHILL, DEWSBURY, YORKS. TEL: 1691-2 'GRAMS: 'TRANSFORMA, DEWSBURY'

M·A·N



Dam crest crane of 160 tons capacity for moving the emergency gates of 3.05 x 6.59 m against a water head of 95 m, for the Dokan Dam, Iraq.

HYDRAULIC STRUCTURES

MASCHINENFABRIK AUGSBURG-NÜRNBERG AG · GUSTAVSBURG WORKS
GUSTAVSBURG/HESSEN (GERMANY) REPRESENTATIVES IN ALL COUNTRIES

Type U106 (0.6m³) Hitachi Power Shovel

HITACHI CONVERTIBLE SHOVEL

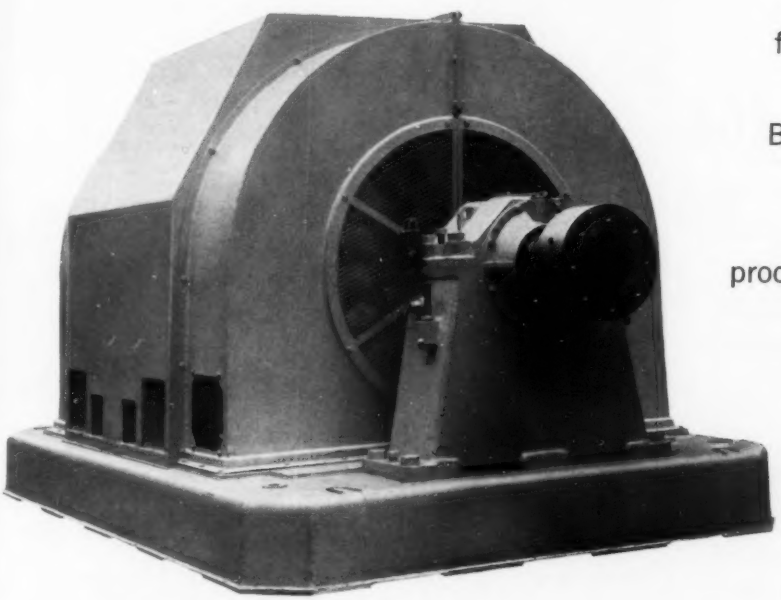
There's little glamour about a machine designed for engineers by engineers – men who are unsatisfied with anything less than constant, top efficiency.

The rugged Hitachi Convertible Shovel has been built for smooth and fast operation under the toughest conditions, from the tips of its wear-resistant cast steel dipper teeth to its stable, extra long and wide truck frame. The versatile Hitachi Convertible Shovel offers a choice of diesel engine or electric induction motor as prime mover, can be mounted on crawlers or truck for still higher mobility. The efficient Hitachi Convertible Shovel converts quickly and readily to dragline, drag shovel, clamshell, crane or piledriver. Literature and quotations gladly supplied on request.

Hitachi, Ltd.
Tokyo Japan
Cable Address: "HITACHY" TOKYO

INDUCTION GENERATORS

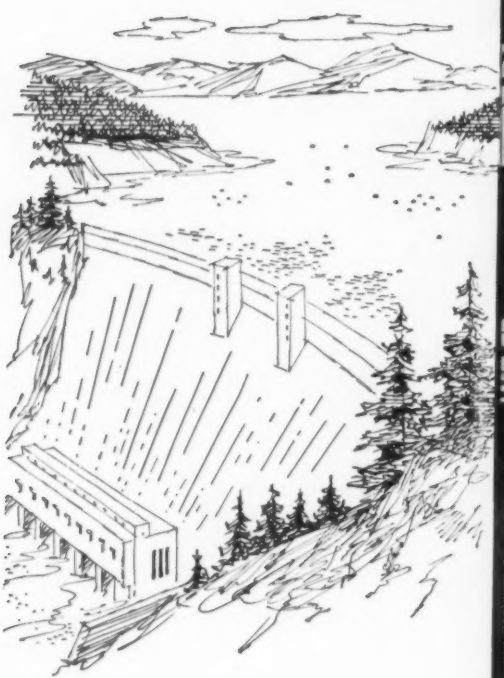
25 MW-

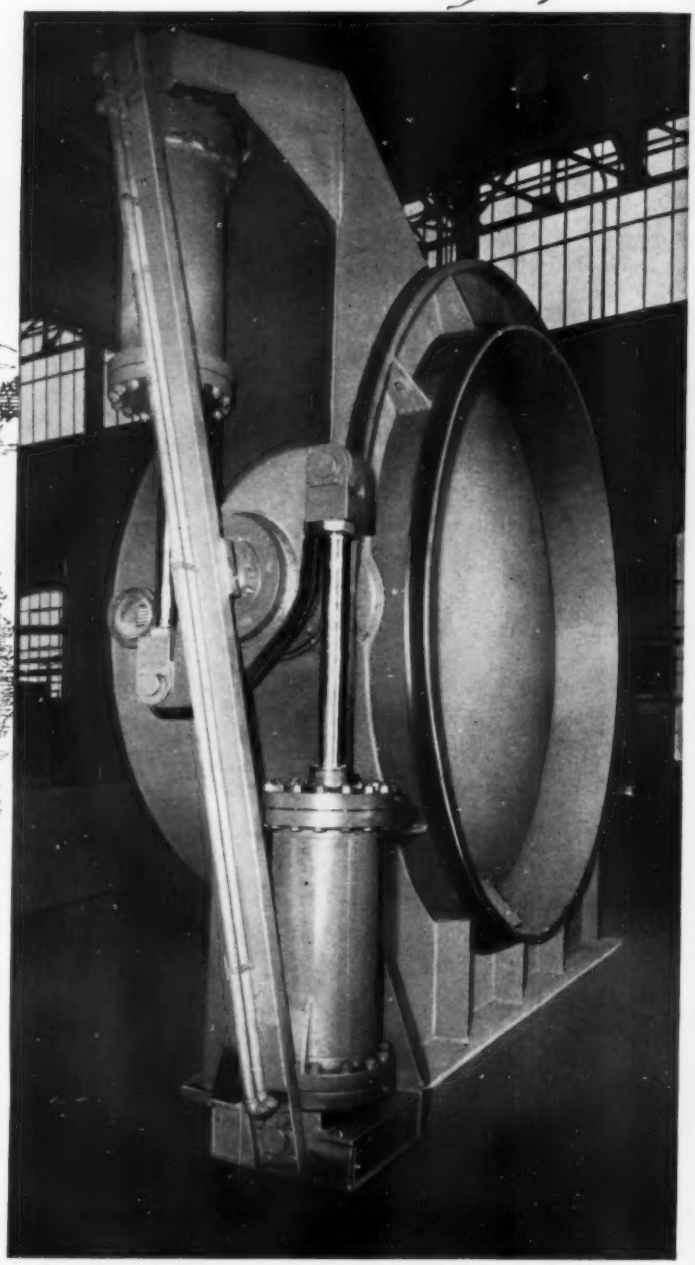


This is the total output of the forty-odd induction generators already supplied by Bruce Peebles in sizes ranging from 30kW to 4MW for hydro-electric and industrial process energy recovery schemes in the United Kingdom.

BRUCE PEEBLES & CO. LIMITED EDINBURGH

Butterfly Valves





Designed for 80 p.s.i. water pressure and emergency closing against flow of 1,680 C.F.S. under 123 ft. head, the illustration shows a shop photo of one of three 12'-0" Turbine Shut-off Butterfly Valves built for a progressive mining Company in Quebec.

The valve body and disc are entirely fabricated from Steel Plate with the seal seat and disc seal of Stainless Steel. The seal of the disc is adjustable.

Another example of the fine engineering Industry expects from the shops of Canadian Vickers.

CANADIAN VICKERS LIMITED

MONTREAL • TORONTO

MEMBER OF THE VICKERS GROUP

One of the 180,000 kVA 13·2/120 kV three phase 60 cycles transformers being lowered into the hold of the ship at Manchester, England en route for Lewiston.

FERRANTI TRANSFORMERS
for
NIAGARA PROJECT
LEWISTON POWER PLANT

Ferranti Ltd. are proud to have supplied six 180,000 kVA 13·2/240 kV and seven 13·2/120 kV three phase Generator Transformers for the Lewiston Power Plant of the Power Authority of the State of New York.

The transformers are forced-oil, forced-water cooled, inert gas-filled type, and each will be directly coupled to a 167,000 kVA three phase Generator.

FERRANTI TRANSFORMERS ARE FAMOUS THROUGHOUT THE WORLD

FERRANTI LTD · HOLLINWOOD · LANCS · Telephone: FAIlsworth 2000
London Office: KERN HOUSE · 36 KINGSWAY · W.C.2 · Telephone: TEMple Bar 6666

FT 265/2

S.W.S. Type UEI.

The ONLY

33kV

PACKAGE SWITCHGEAR

fully proven in service

all over the world

UNITED KINGDOM

BORNEO

HONG KONG

U.S.S.R.

SOUTH AFRICA

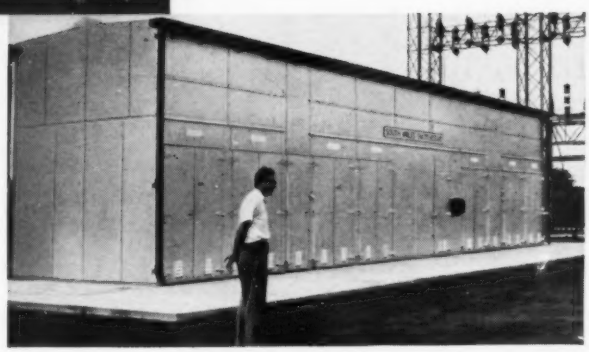
WEST INDIES

SOUTH AMERICA

Over the past years S.W.S. type UEI metal-enclosed switchgear has earned a world wide reputation for reliability in service. Since its introduction this 33kV vertically isolated, single and duplicate busbar package unit has proved all claims made for it.

Simplification of preparatory site work and complete assembly at the works make for easy and fast erection ; the package unit illustrated bottom right was erected in 21 days.

Safety in service in any climatic conditions is ensured by the porcelain insulation and the design allows 'in situ' inspection in all weathers.
WRITE FOR FURTHER DETAILS



33kV Package Switchgear Unit in South America.

33kV Package Switchgear Unit in South Africa.

SWS

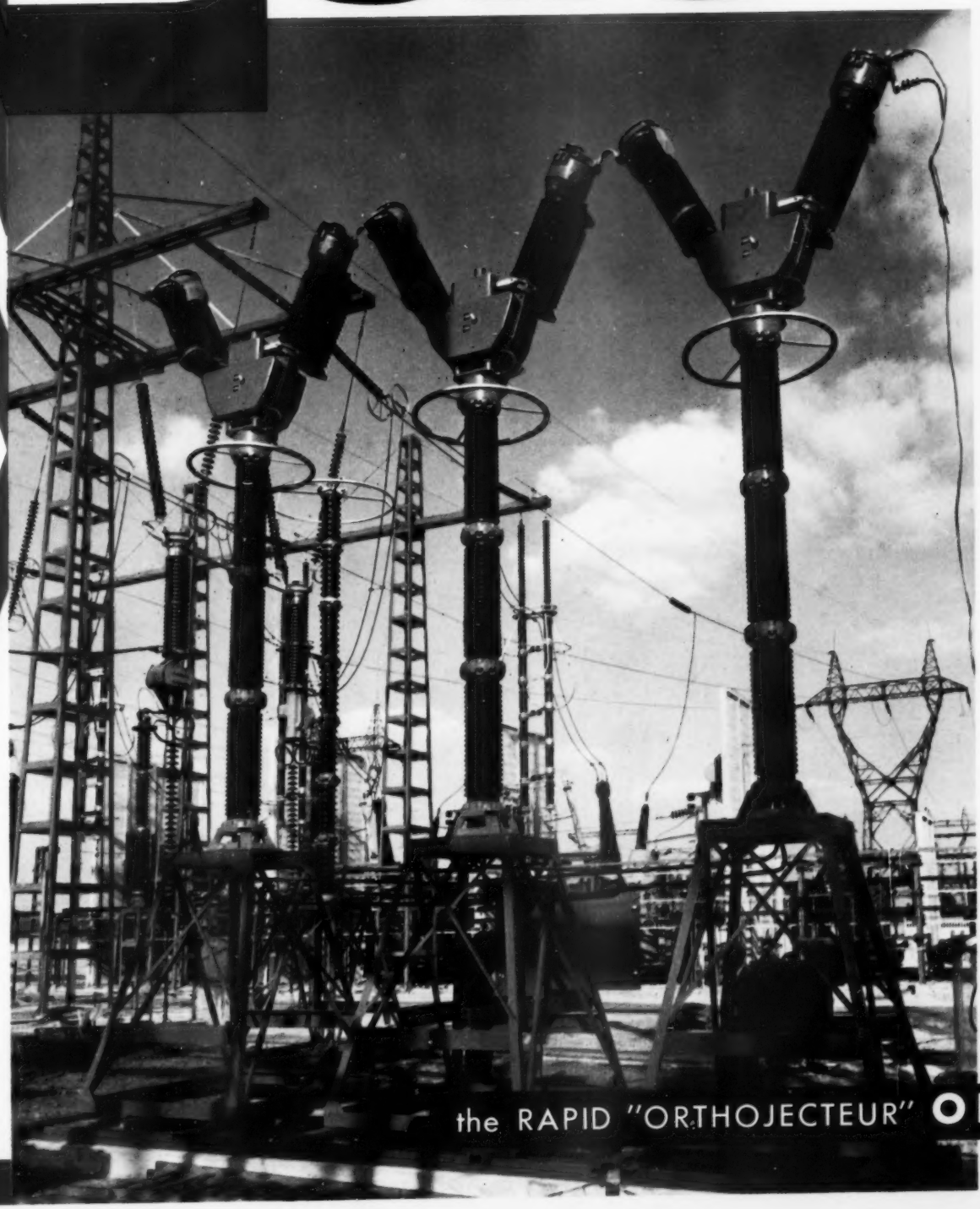
SOUTH WALES SWITCHGEAR LIMITED

A MEMBER OF THE ASSOCIATED ELECTRICAL INDUSTRIES GROUP OF COMPANIES

WORKS: TREFOREST. BLACKWOOD, ABERBARGOED

SW 30

Delle



the RAPID "ORTHOJECTEUR" **OR**

uit-breaker pole of
il content **Rapid**

new performances...

achieved by small oil content circuit-breakers

with the rapid "Orthojecteur" OR

A pole of the rapid "Orthojecteur" **OR 420 kV** has performed at CRENEY sub-station, under the supervision of "Electricité de France":

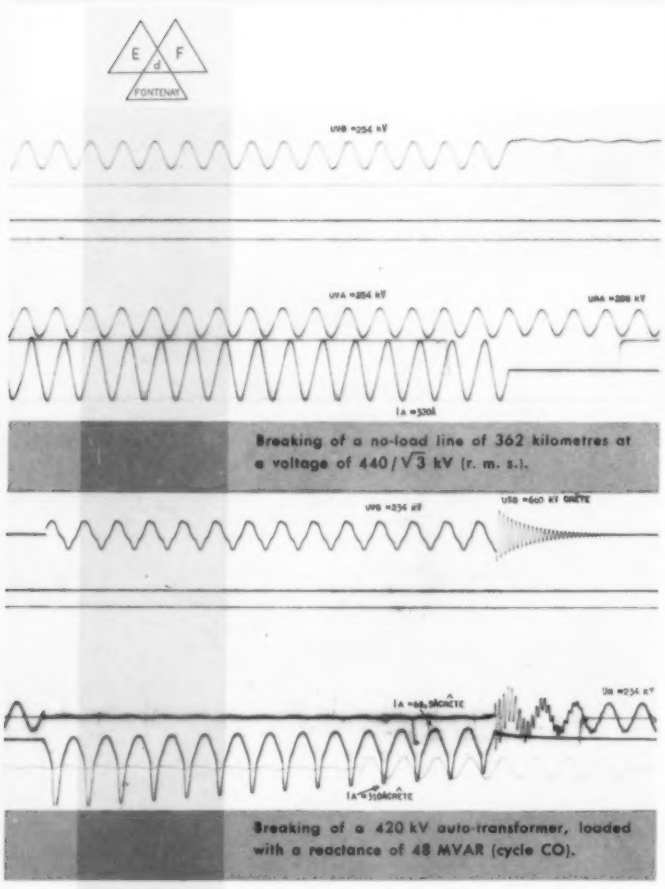
50 tests of breaking of no-load lines and inductive currents

not only

satisfying conditions laid down in the specifications of "Electricité de France"

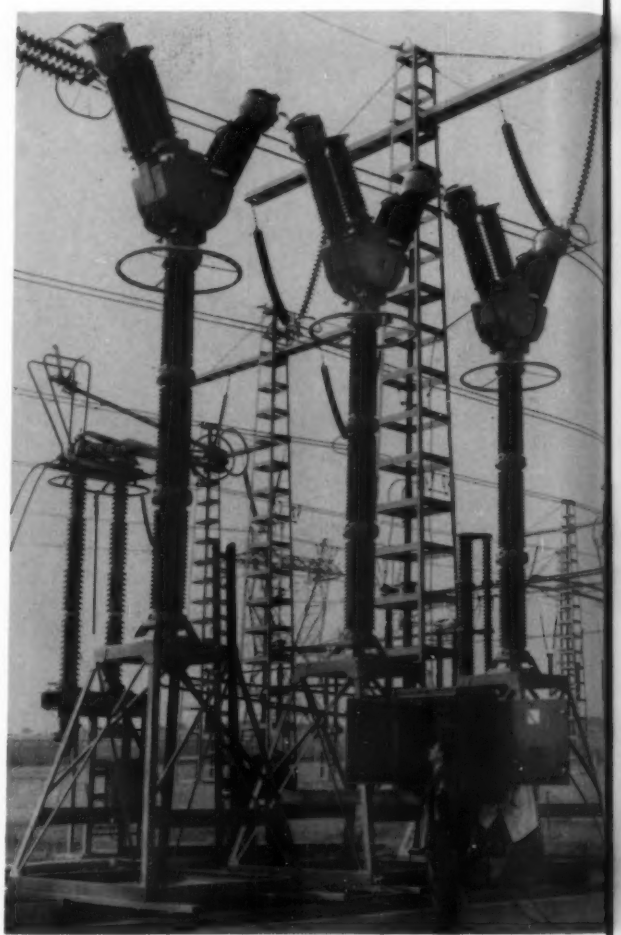
but also

without restriking or reignition while breaking no-load lines.



Breaking of a no-load line of 362 kilometres at a voltage of $440/\sqrt{3}$ kV (r. m. s.).

Breaking of a 420 kV auto-transformer, loaded with a reactance of 48 MVAR (cycle CO).



A circuit-breaker pole of small oil content RAPID "ORTHOJECTEUR" OR under test on the french network of 380,000 volts.

ATELIERS DE CONSTRUCTIONS ELECTRIQUES DE

Delle

DE LA COMPAGNIE GENERALE D'ELECTRICITE

HEAD OFFICE AND HIGH VOLTAGE DEPARTMENT / 130 RUE LEON-BLUM VILLEURBANNE RHONE FRANCE

We design
manufacture and erect

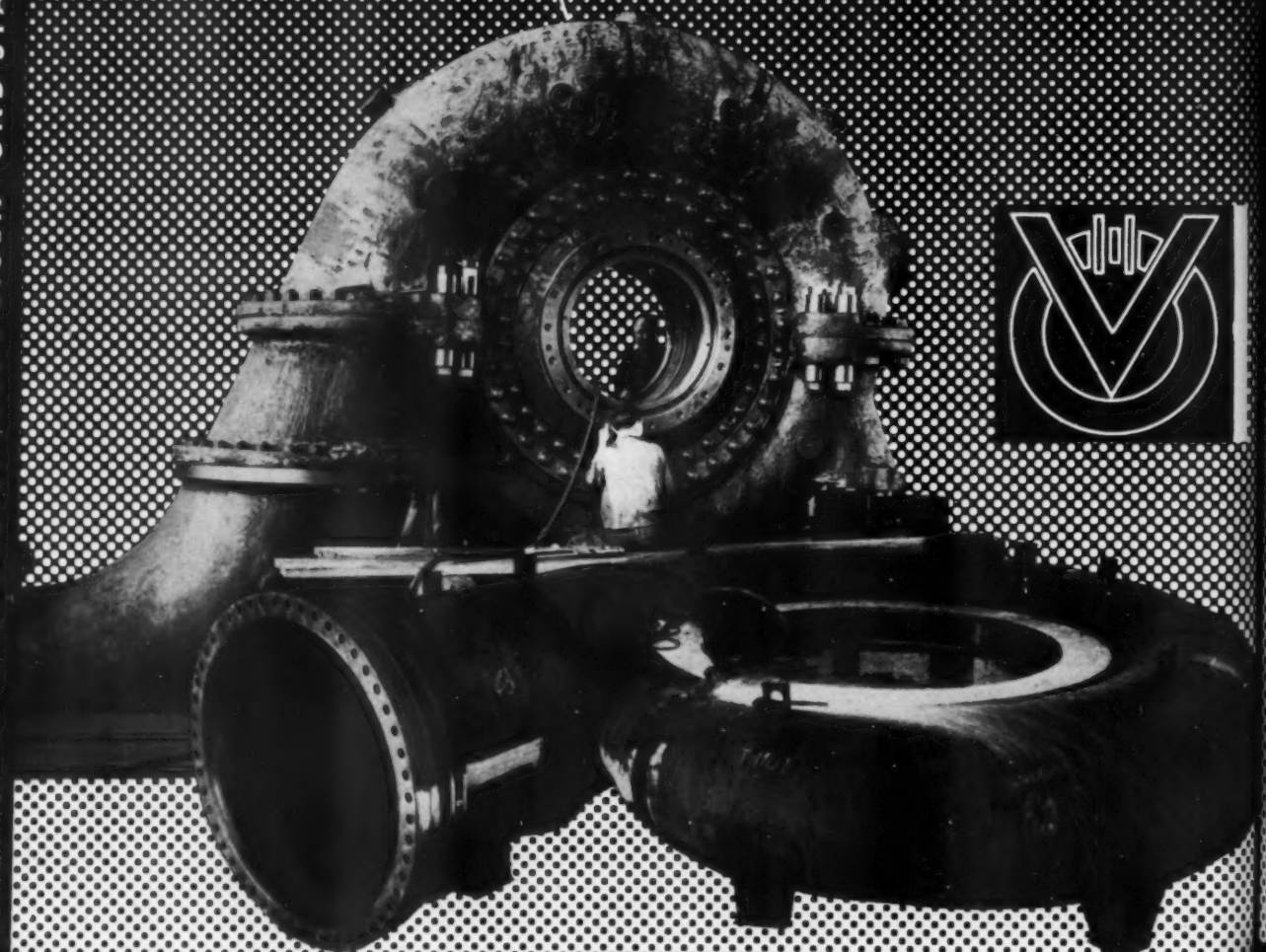
PENSTOCKS

VÖEST

VEREINIGTE ÖSTERREICHISCHE EISEN- UND STAHLWERKE, LINZ-DONAU, AUSTRIA

Hydraulic Turbines, Spherical and Butterfly Valves

Licensed by Baldwin-Lima-Hamilton Corp.
Philadelphia, U.S.A.



VERE

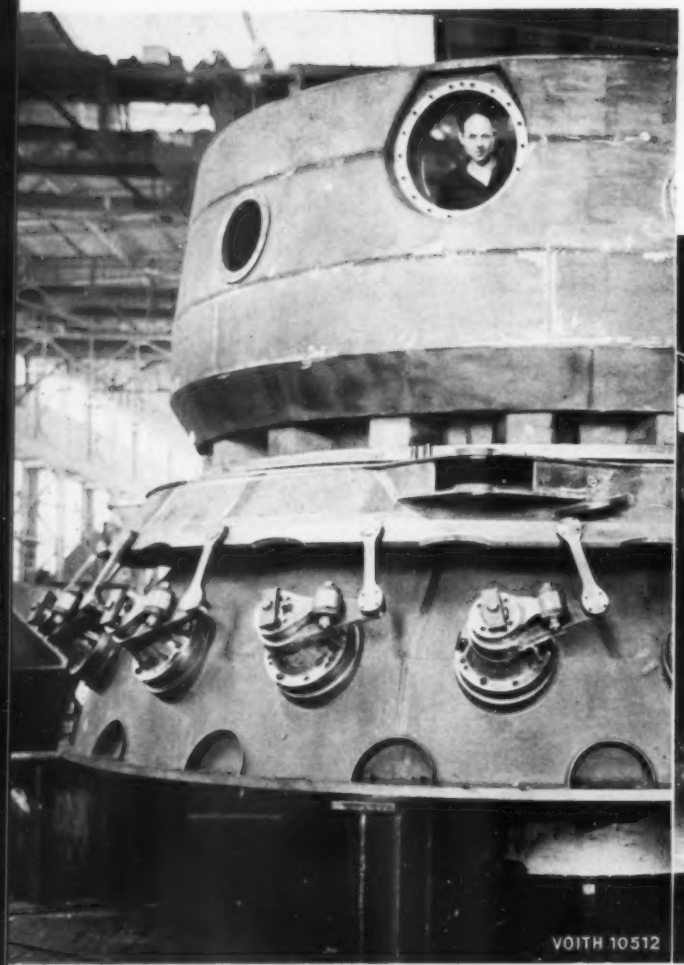
VÖEST

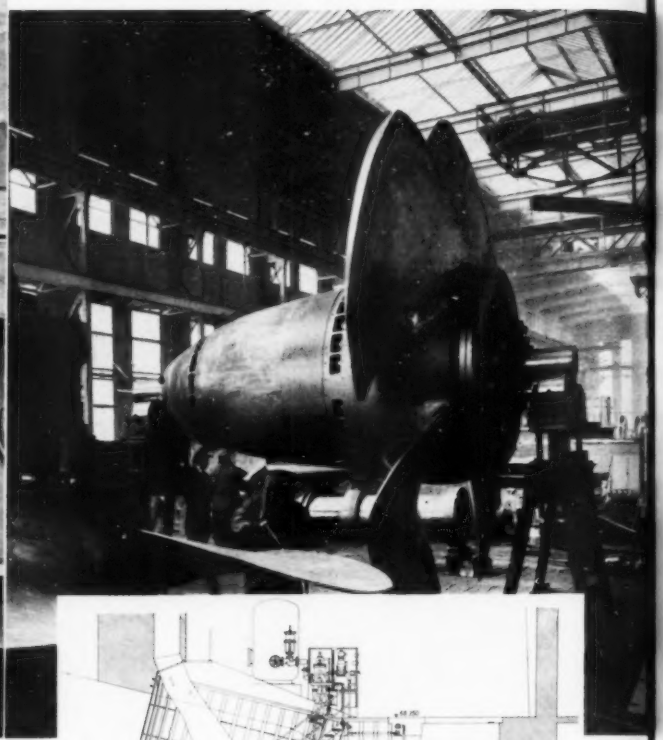
HYDRAULIC STEEL CONSTRUCTION

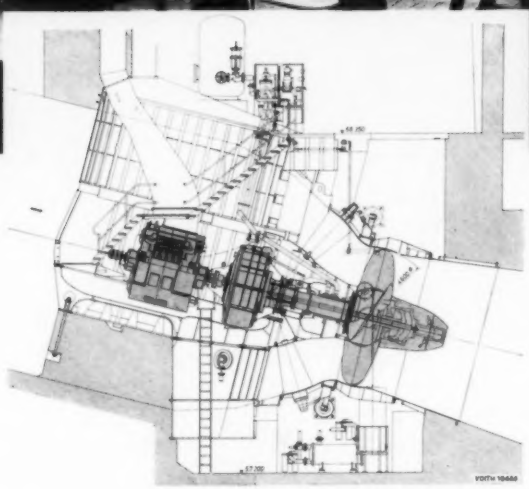
Steel structures for weirs and loch gates of every type, including the required auxiliary equipment; mechanical and hydraulic drives hereto sprocket chains; trash rake cleaning machines; weir cranes.

VEREINIGTE ÖSTERR. EISEN- UND STAHLWERKE, LINZ-DONAU

VOITH







The workshop photos and the drawing show Voith equipment for the Moselle Power Station Project

26,000 h.p.

Voith equipment for the Moselle Power Station Project:

2 tubular pump-turbines

and

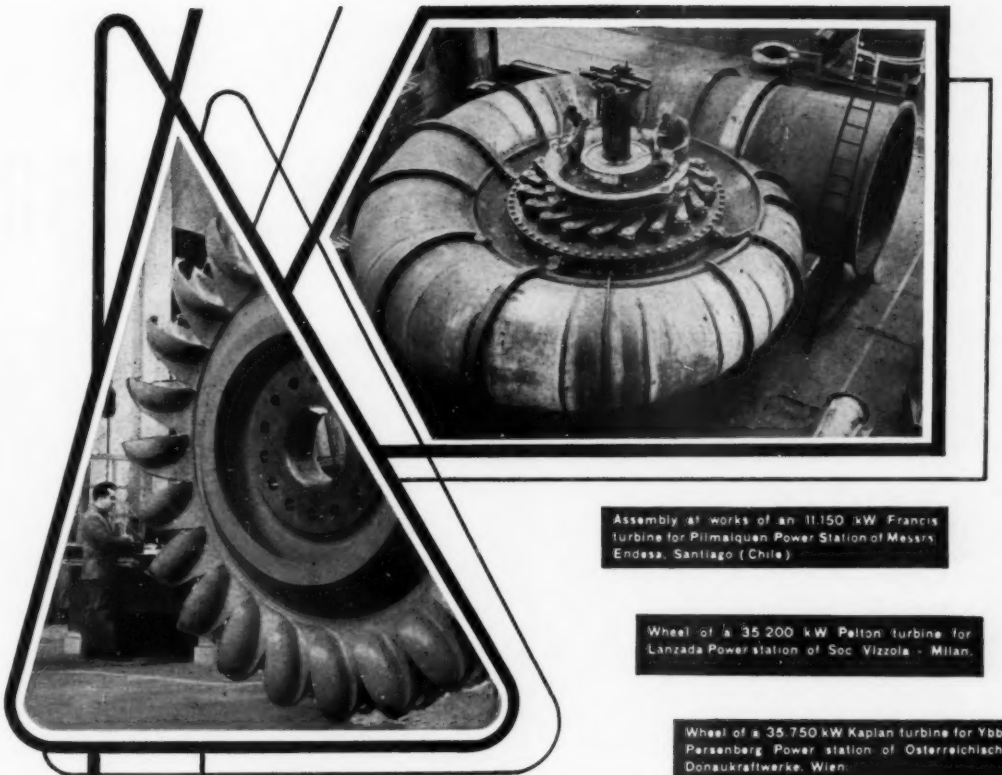
2 tubular turbines

for the Lehmen Hydro-Electric Power Station,

head 5.3 m (about 17'5").

J. M. VOITH GMBH · HEIDENHEIM (BRENZ) · GERMANY

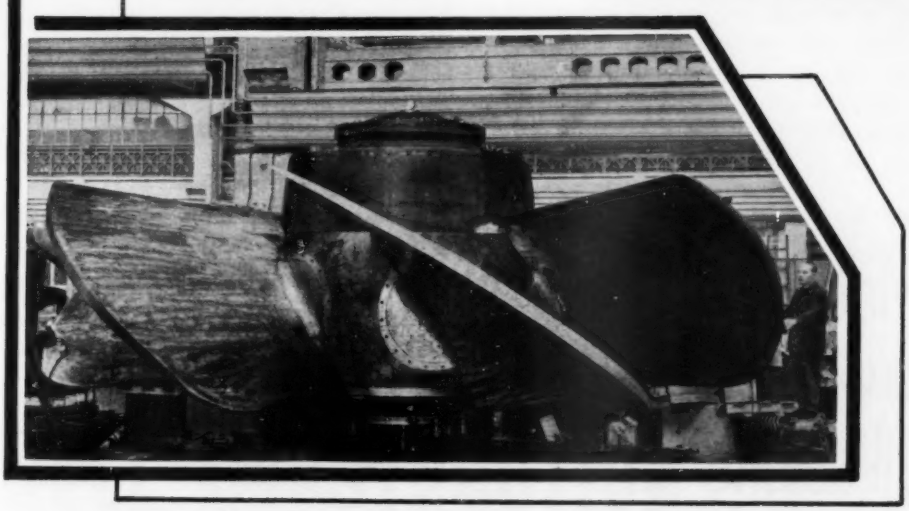
Complete hydro-electric plants



Assembly at works of an 11.150 kW Francis turbine for Pilmaiquen Power Station of Messrs Endesa, Santiago (Chile)

Wheel of a 35.200 kW Pelton turbine for Lanzada Power station of Soc. Vizzola - Milan.

Wheel of a 35.750 kW Kaplan turbine for Ybbs Persenberg Power station of Osterreichische Donaukraftwerke, Wien.



ANSALDO-SAN GIORGIO
GENOVA

AEI INSTRUMENTATION INFORMATION SERVICE

THE FIRST BELLOWS FLOW METER WITH DIRECT FLOW INDICATOR

AEI/Barton bellows flow meters can now be supplied with pneumatic motion transmitter containing a direct flow indicator which is *completely independent of air supply*. The pointer is mechanically linked to the torque tube. AEI/Barton flow meters, which employ the original and world-accepted Barton double-bellows system, once again lead with this valuable safety feature.

With ranges from 0-25" w.g. up to 0.40 p.s.i., static pressures up to 6,000 p.s.i., a sensitivity of 0.02% of full scale and linearity within 0.5% of full range, the AEI/Barton flow meter can out-perform any comparable instrument. *AND* list price for the instrument illustrated is from £98 (100% stainless steel body at little extra cost).

Mail this coupon for full details

Please send me a copy of Publication 1112 giving specification of the AEI/Barton flow meter range.

NAME .....

POSITION .....

COMPANY ADDRESS .....

.....

AEI

Instrumentation Division
P.O. Box 1 · Harlow · Essex · Tel: Harlow 25271
Associated Electrical Industries Limited

SC/106

Top of Surge Shaft,
St. Fillans, Perthshire.
Consulting Engineers :
Sir M. MacDonald & Partners

800 feet deep

Part of one of the Hydro-Electric contracts entrusted to
the Mitchell Construction Co. Ltd., the 28 ft. diameter
Surge Shaft and 10 ft. diameter Penstock Shaft at St. Fillans
which form a continuous vertical shaft 800 ft. deep.
By employing a new and specially developed method of shaft raising,
Mitchell Construction excavated the 600 ft. Penstock Shaft
out of solid rock at an average rate of 64 ft. per week,
with a maximum advance of 138 ft. in one week;
such a rate of advance would have been impossible with the employment
of conventional techniques on a shaft of this size.

MITCHELL CONSTRUCTION

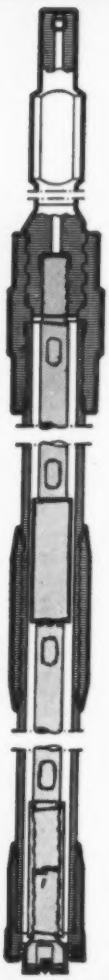
Building and Civil Engineering Contractors

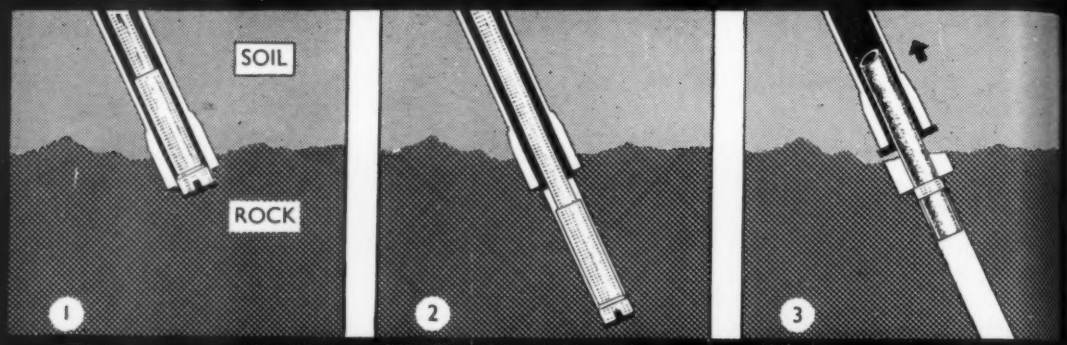
THE MITCHELL CONSTRUCTION COMPANY LTD

Wharf Works, Peterborough

P.3060

THE OVERBURDEN DRILLING METHOD





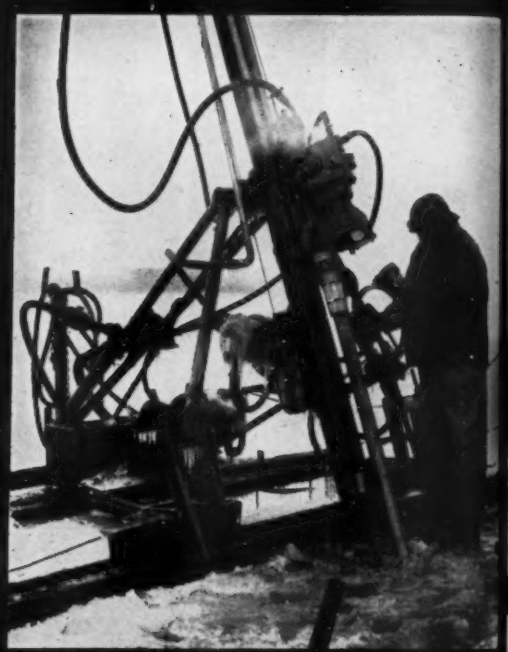
Drilling and blasting bed rock without removing the soil cap

Drilling is carried out using an Atlas Copco rock drill with separate rotation. Extension equipment (left) consists of Sandvik Coromant drill-pipes with ring bit and inner extension steels with cross bit. The bits are tipped with tungsten-carbide inserts.

1. Pipe and steel are drilled simultaneously through sub-soil layers until pipe is collared a few inches in bed-rock.

2. Pipe is uncoupled from drilling action and hole drilled to full depth by inner extension steels alone.

3. Inner steel is withdrawn and replaced by plastic tube. Drill-pipe is removed leaving expendable tube connection between surface and rock for charging.



NEW TECHNIQUE WIDENS SCOPE FOR SUB-SOIL AND UNDER-WATER DRILLING

The Overburden Drilling Method is a completely new technique for drilling through earth strata and under water. It has proved itself simpler, cheaper and more versatile than conventional methods used for grouting, sub-soil exploration, mineral prospecting and similar operations. Underlying boulders are drilled through and reamed without need for blasting or removal. Sampling can be carried out at any stage of the drilling.

The method involves the use of specially developed extension drill-pipes with inner extension steels. These are driven by the Atlas Copco BBE rock drill with separate rotation. By means of a special shank adaptor, percussion and powerful torque are conveyed to the pipe which can be uncoupled from the drilling action. Removal of the inner steels from the pipe leaves an open connection with the surface and widens the scope for a variety of applications.

Overburden Drilling was originally introduced by Sweden's largest contracting company, AB Skånska Cementgjuteriet, for their Lindö Canal project. In constructing this 4-mile seaway to the Baltic about 226,000 cu. yds. of rock and more than 4,500,000 cu. yds. of overburden were blasted and excavated by dredging.

Atlas Copco puts compressed air to work for the world

SALES AND SERVICE IN OVER 100 COUNTRIES

Write for the Overburden Drilling booklet to:
Your local Atlas Copco company or agent or to Atlas Copco AB, Stockholm 1, Sweden.

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WP/02

BUILDING FOR POWER

Huwood Conveyors are in wide use, not only in Britain but throughout the world—one of their most important applications being in the work of dam building for hydro-electric schemes.

They have been chosen because they offer the highest degree of adaptability to varying sites, the utmost reliability, and the minimum of routine maintenance.

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Industrial and Export Office
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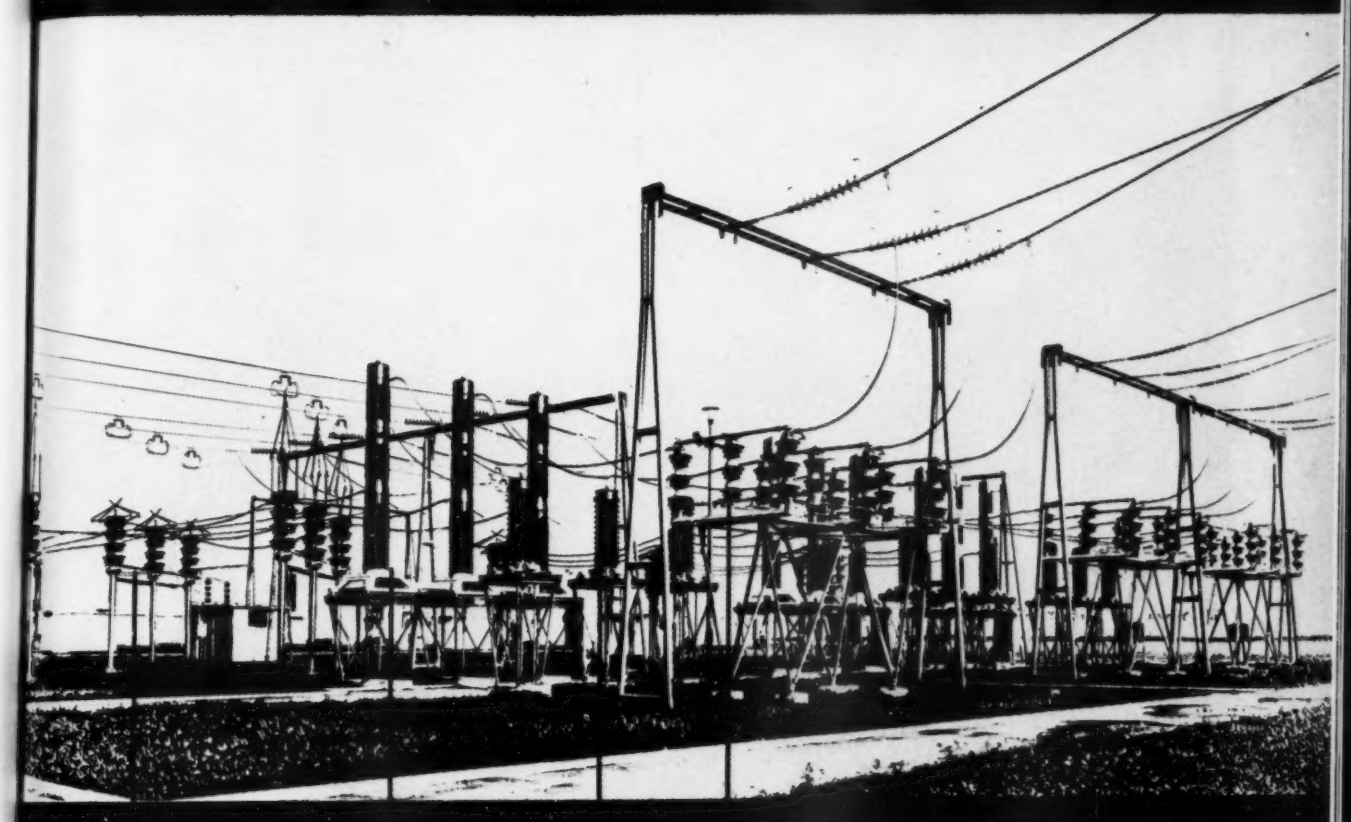
Telegrams: Huwood Stock, London. Telephone: Monarch 3273 (4 lines).

SCARPA E MAGNANO



Pantograph isolators

Small-oil-volume circuit breakers

Potential and current transformers

Rotating disconnecting switches

Control and signal switchboards

Bushings and through-wall bushings

Scarpa e Magnano switchgear has now spread all over the world. This success is due to good engineering, constant research of the most efficient design, severe tests and careful inspection at all stages during the manufacture, which undoubtedly assure safety of operation under the heaviest service conditions. Above all, the various products benefit by a forty-years-old manufacturing experience. This is why Scarpa e Magnano trade-mark stands for "safety".

GILKES STANDARD HYDRO-ELECTRIC UNITS

Ratings	5—25 kW
Head	100—300 feet (30.5—91.5 metres)
Frequency	50 or 60 cycles

These units have been designed to provide a reliable source of A.C. power for isolated communities where installation costs have to be a minimum and no skilled maintenance is available.

A few carefully chosen sizes and ratings cover the range and facilitate standardisation of parts.

Leaflet M.22 available upon request.

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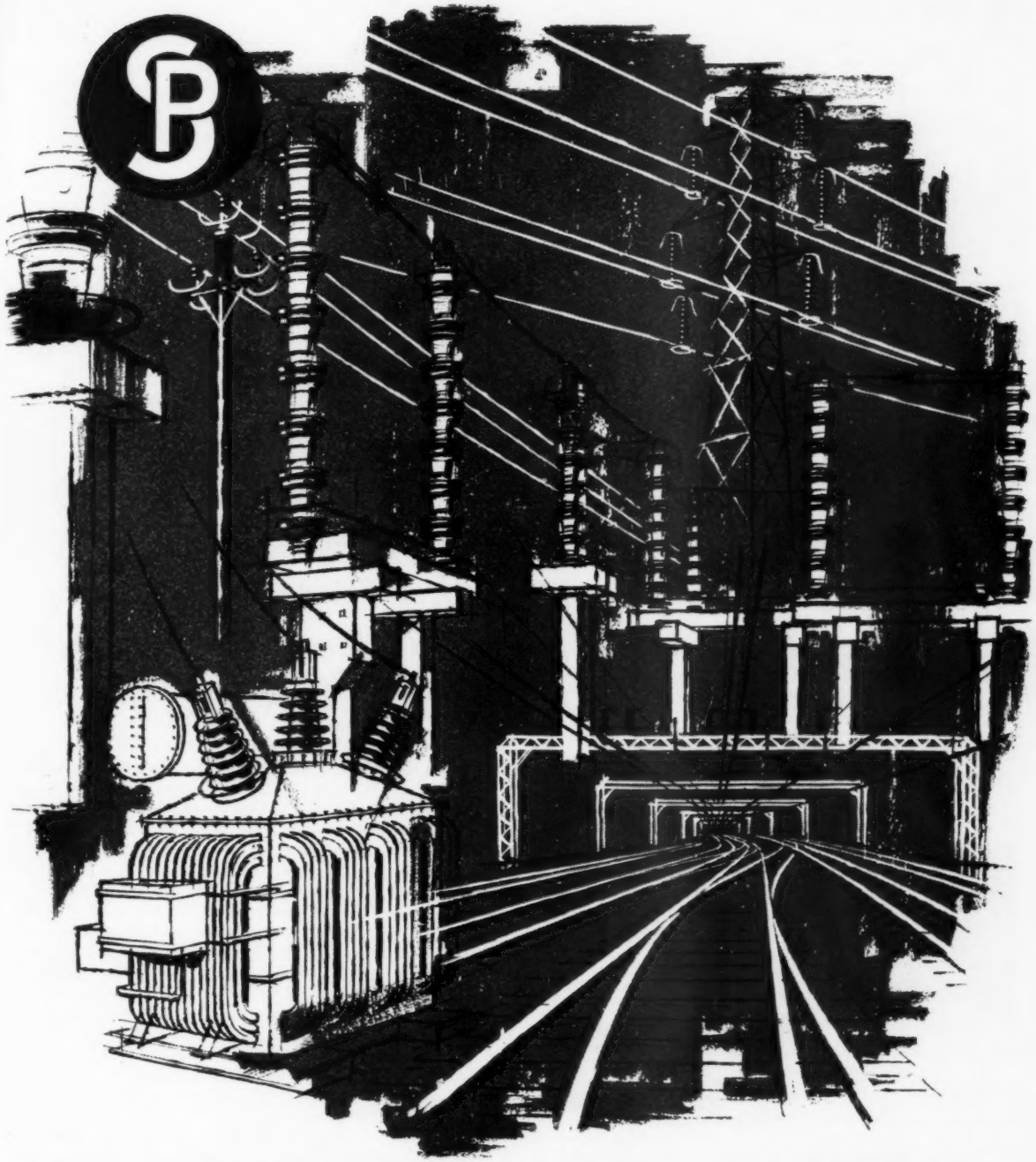
London Office: CRAVEN HOUSE, KINGSWAY, LONDON, W.C.2. Tel: HOLBORN 3231

GI21



HIGH VOLTAGE INSULATORS

The outstanding quality of S & PP insulators is the result of over 30 years' experience in the manufacture of high voltage porcelain insulators.

- **Overhead line insulators**
- **Switchgear post insulators**
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STEATITE AND PORCELAIN PRODUCTS LIMITED

STOURPORT ON SEVERN, WORCS. TEL: STOURPORT 2271 GRAMS: STEATAIN, STOURPORT S.P.103

"still giving excellent service after 36 years"—that's the report from Arkansas Power & Light on three Leffel Turbines at Remmel Dam

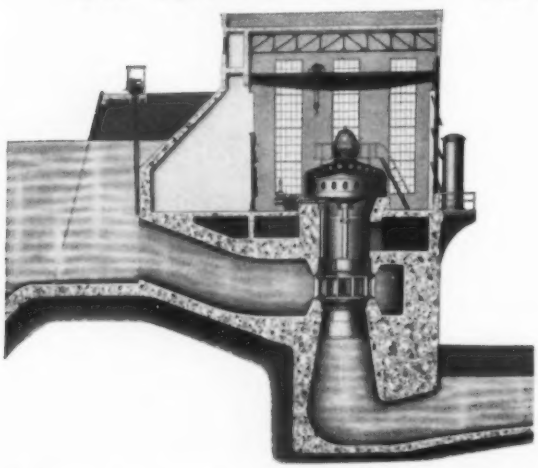

Photo above shows Remmel Dam as it appears today. The dam is located on the Ouachita River near Hot Springs, Arkansas. Seventy-five feet high and 900 feet long at the apex, it creates Lake Catherine, with a total area of 2624 acres. Drawing shows a cross-section of the Remmel Dam power house, unusual in that the turbines are installed at a height of 19' above tail water.

In 1924, three Leffel vertical shaft turbines were installed at the Arkansas Power & Light Company's Remmel Dam hydro-electric station . . . Arkansas's first major hydro-electric facility.

In addition to the three turbines, each rated 5700 H.P. at 120 R.P.M. under a 50 foot net head, Leffel also furnished the outside gate equipment for the Remmel Station.

Arkansas Power & Light's report, after 36 years of operating experience, boils down to "very well pleased with the equipment, which is still operating satisfactorily . . . very little in the way of repairs required during the 36 years."

An unusual case? Not for Leffel. Long life and reliable service are the routine, not the exception for Leffel turbines. That's why satisfied Leffel customers in all parts of the world, like Arkansas Power & Light, will turn to Leffel for help on their next hydro-electric project, whether it be a completely new installation or the rehabilitation or expansion of existing facilities.

You, too, can take advantage, without obligation, of Leffel's nearly a century of experience in designing and building fine hydraulic turbines. Just drop us a line outlining your requirements, or the nature of your water power problem.

1114-E

FOUNDED IN 1862

THE JAMES LEFFEL & CO.

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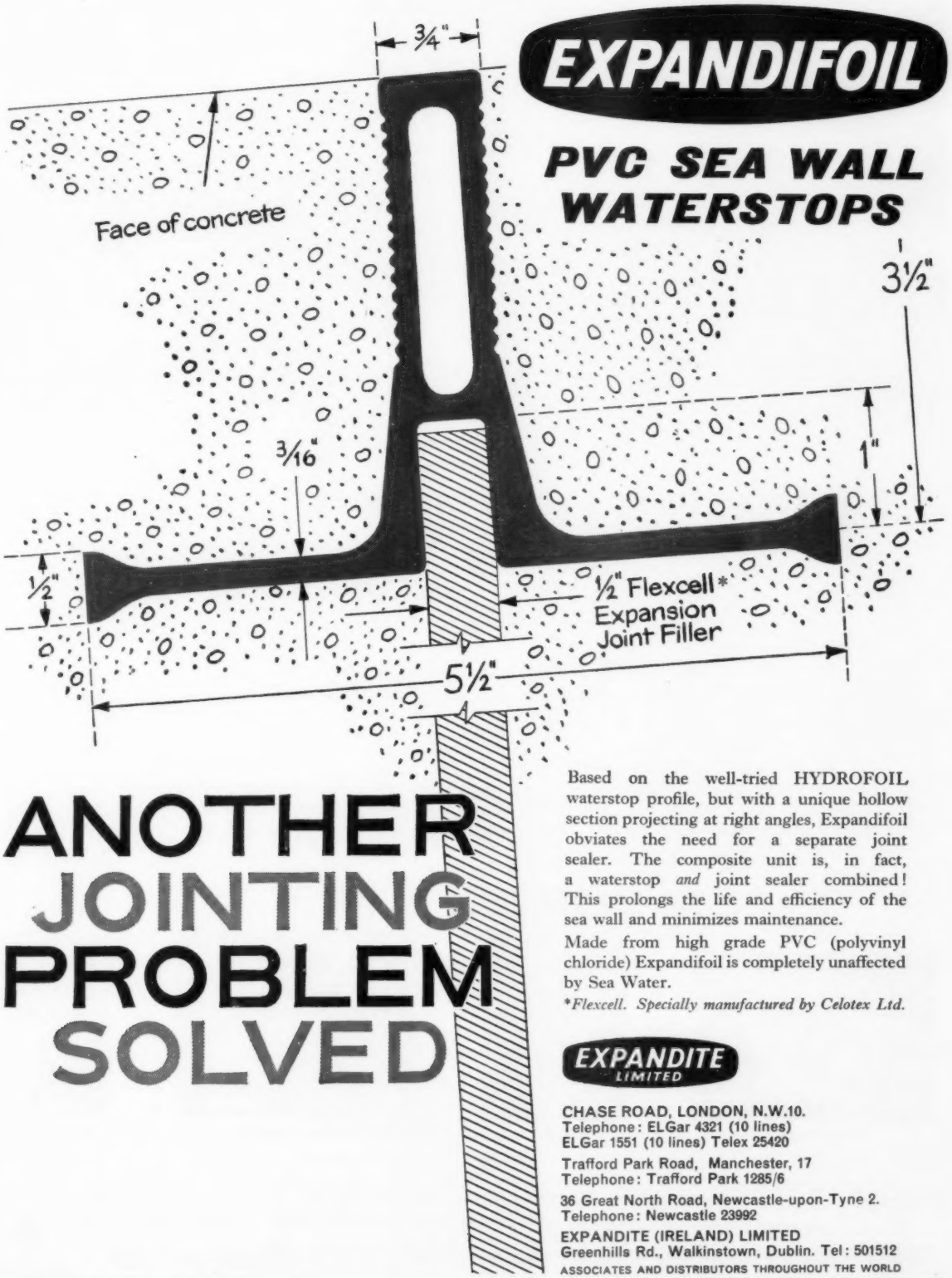
MORE EFFICIENT HYDRAULIC POWER FOR 99 YEARS

EXPANDIFOIL

PVC SEA WALL WATERSTOPS



ANOTHER JOINTING PROBLEM SOLVED

Based on the well-tried HYDROFOIL waterstop profile, but with a unique hollow section projecting at right angles, Expandifoil obviates the need for a separate joint sealer. The composite unit is, in fact, a waterstop *and* joint sealer combined! This prolongs the life and efficiency of the sea wall and minimizes maintenance.

Made from high grade PVC (polyvinyl chloride) Expandifoil is completely unaffected by Sea Water.

**Flexcell. Specially manufactured by Celotex Ltd.*

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Specialize in galvanised steel structures throughout the World.

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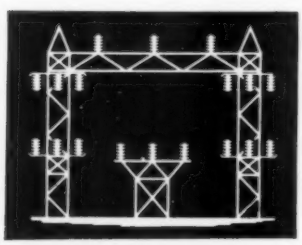
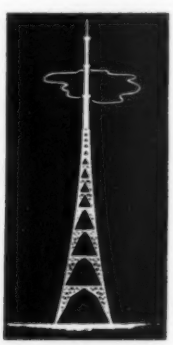


SUBSTATION STRUCTURES



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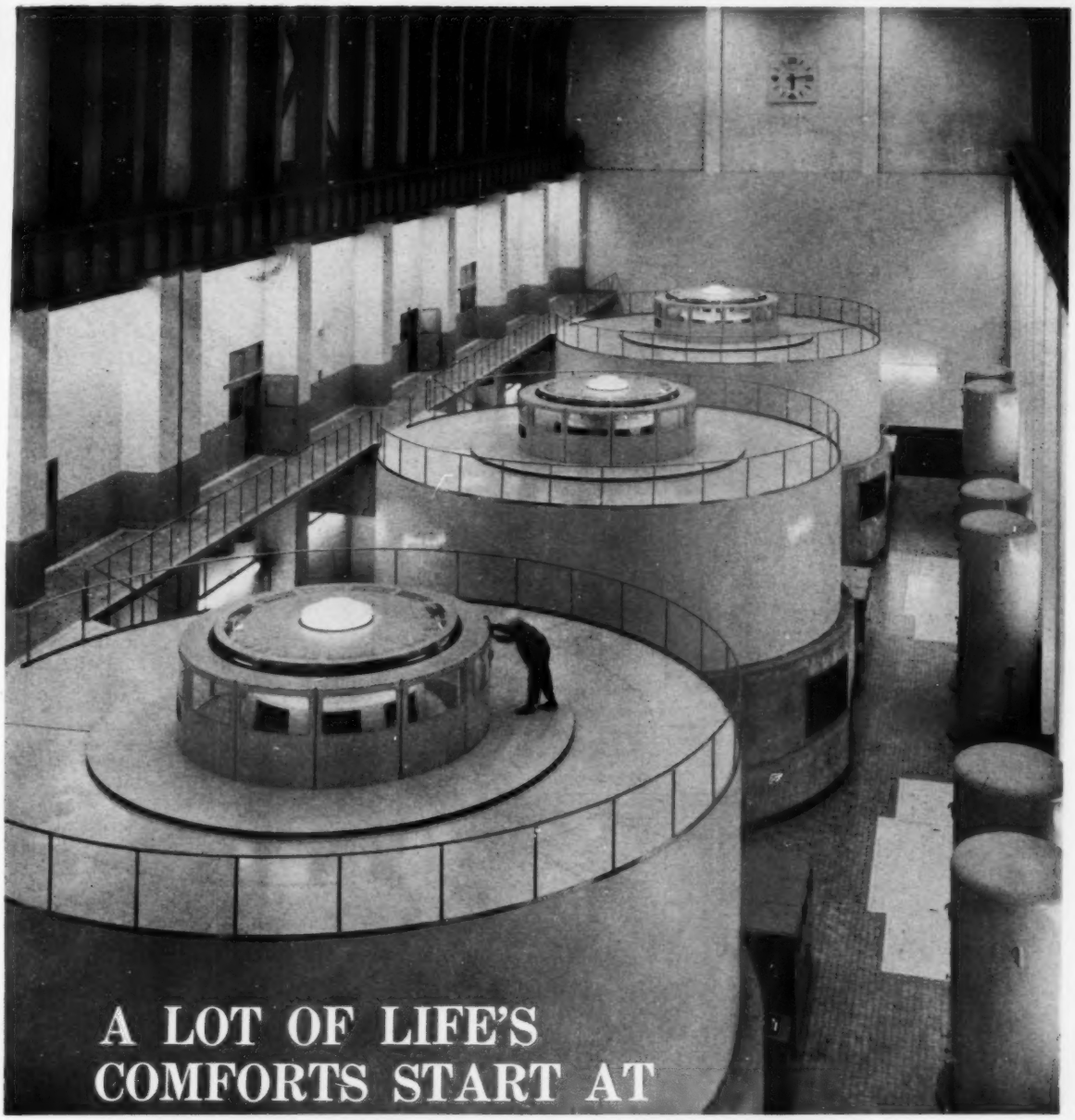
105,000 kVA Water-Wheel Generators



A LOT OF LIFE'S
COMFORTS START AT

MITSUBISHI ELECTRIC

When you think of giant generators, you rarely think of their vital part in making this world a more comfortable place to live in. Yet Mitsubishi Electric's great generators and transformers, plus many large and small home appliances all do just that..... every day in countless ways. Backed by a long history of outstanding achievements, distinguished by the famous Mitsubishi Brand. Do think about it the next time you see the THREE DIAMONDS on an electric appliance.

MITSUBISHI ELECTRIC MANUFACTURING COMPANY

Head Office: Tokyo Building, Marunouchi, Tokyo **Cable Address: MELCO TOKYO**

SAVE TIME LABOUR MONEY

switch to LIMITORQUE push-button valve control

To-day, in industries where liquid has to be controlled, more and more people are converting their hand-operated valves to LimiTorque. For with LimiTorque, the actuator with push-button control, one man does the work of many—simply and efficiently. What does switching to LimiTorque entail ? In almost every case, no more than minor changes to the valve. Highly sensitive and automatic, LimiTorque is easily adapted for use with all types of valve.

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NGK

SOLID CORE INSULATORS

Puncture-Proof Performance

Unlike conventional hollow insulators, which must be protected against moisture seepage with a sealed joint at the bottom, NGK station-post and line-post insulators are of solid-core construction, eliminating moisture seepage and resultant puncture.

This solid-core construction also makes it possible to guarantee a cantilever strength equivalent to that of conventional insulators of much larger diameter. Likewise, the slender body diameter improves anti-pollution performance.

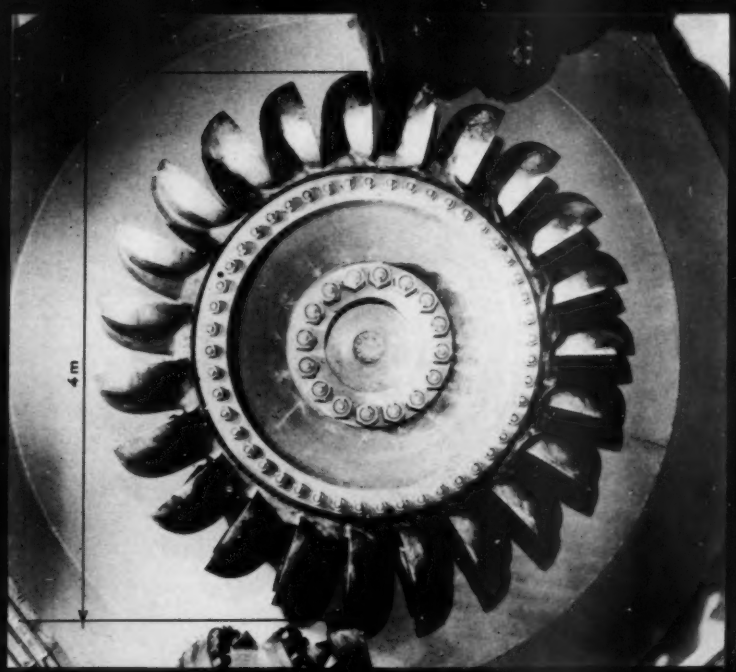
Because of their outstanding qualities of strength, uniformity, and durability, NGK solid-core insulators are gaining in popularity throughout the world.

Cable: INSULATOR NAGOYA. TELEX: NGK-NG9928
Represented in all major territories.

Nippon Gaishi Kaisha LTD.
Mizuho, Nagoya, Japan

Roselend - La Bathie

500 000 kW
from twelve 41750 kW jets
under a 1126 m head



The Roselend plant near Albertville in the French Alps is situated at a height of 1 550 metres above sea level and provides a reserve of some 200 million cubic metres of water for the 500 000 kW power station at La Bathie.

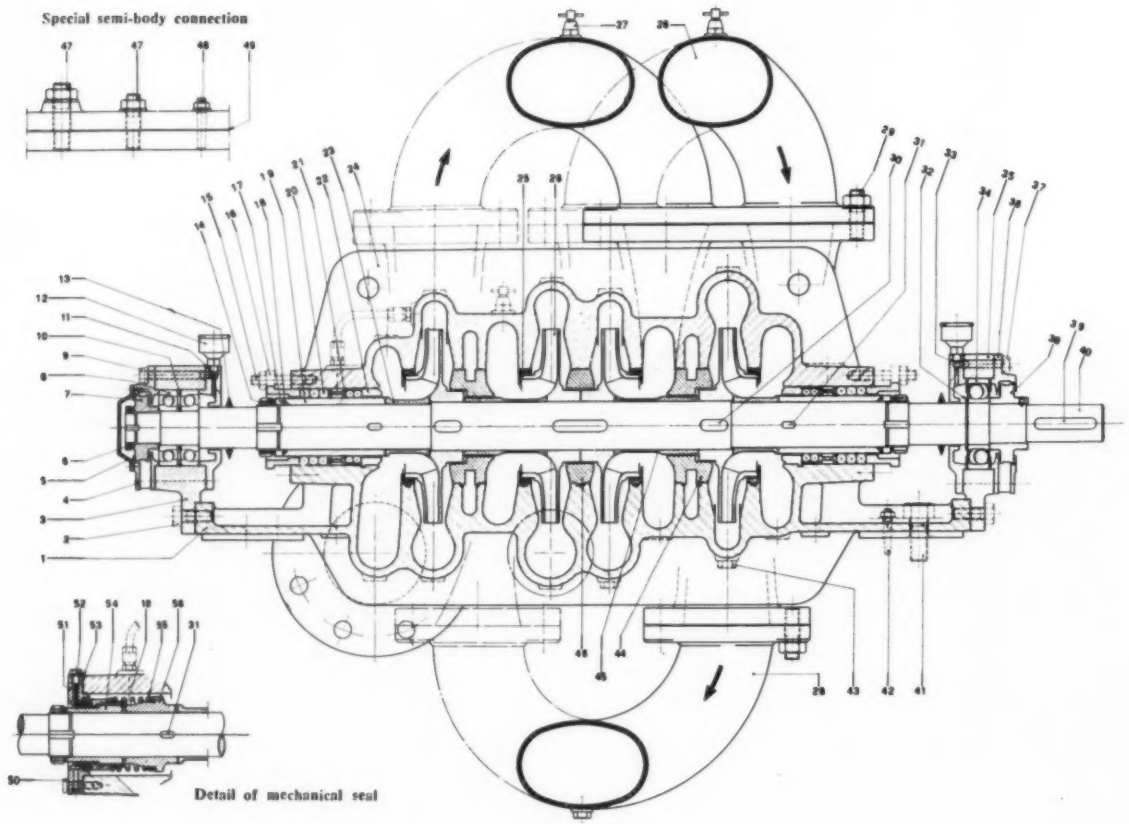
This output is supplied by six 83 500 kW single-runner twin-jet vertical Pelton turbines, each of which is coupled to its own 88 000 kVA alternator running at 428 r.p.m.

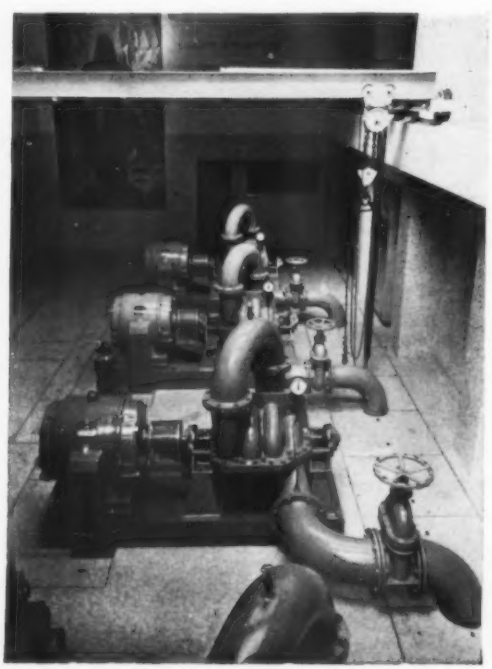
The jets discharge from the individual nozzles under a head of 1126 metres at a speed of 550 kilometres per hour, thus each giving an output of 41 750 kW.
All six of these turbines are **NEYRPIC** - built.

NEYRPIC
Avenue de Beauvert
BP 52 - Grenoble - France
Tel 44-55-30

PD Pump

For water works, storage plants, industrial works, pumping plants.





PD pumps are of the horizontal shaft, single-suction, multi-stage, centrifugal type. Heavy built, these pumps are highly efficient and have every mechanical feature to assure long trouble-free service.

The body of the pump is split in two halves along the horizontal centerline; therefore, it can be easily inspected and quickly dismantled without removing the pump and disturbing the suction and discharge pipe connections. The impellers are in series and opposed in sets, so as to balance the hydraulic pressures. Axial loads on the bearings are thus eliminated, resulting in a more reliable and trouble-free operation of the pump.

The shaft is of high-strength steel and it is lined with protective sleeves where facing the wearing faces of the stuffing boxes with adjustable stuffing glands. Deep boxes accommodate large packing rings. Suitable connections to the sealing supply line are also provided.

Bearing housings of the outboard type, are provided with grease-lubricated heavy duty ball or roller bearings and thrust bearings, for residual or accidental thrusts.

Photo on the left: 2 pumps, type PD 250/300/2, driven by 300 HP NU 2500/4 induction motors, total capacity 24,000 litres (5,280 gallons) per minute, 80-metre (262 ft.) head; 2 pumps, type PD 225/250/2, driven by 200 HP NU 2000/4 induction motors, total capacity 18,000 litres (3,960 gallons) per minute, 80-metre (262 ft.) head. Universal Exhibition Board, Rome.

Please ask for catalogues, price lists, estimates. Our experts are entirely at your service.

PELLIZZARI

Industrie Elettromeccaniche Arzignano - Vicenza - Italy

LOCH GIORRA DAM

The new Giorra Dam shown below was built by Edmund Nuttall, Sons & Co. (London) Ltd., for the North of Scotland Hydro-Electric Board. The dam, which is 1,450 feet long and 100 feet high, stands at the eastern end of Loch Giorra and forms an important part of the Breadalbane Power Scheme.

Authority: North of Scotland Hydro-Electric Board
Consulting Engineers: James Williamson & Partners

EDMUND NUTTALL

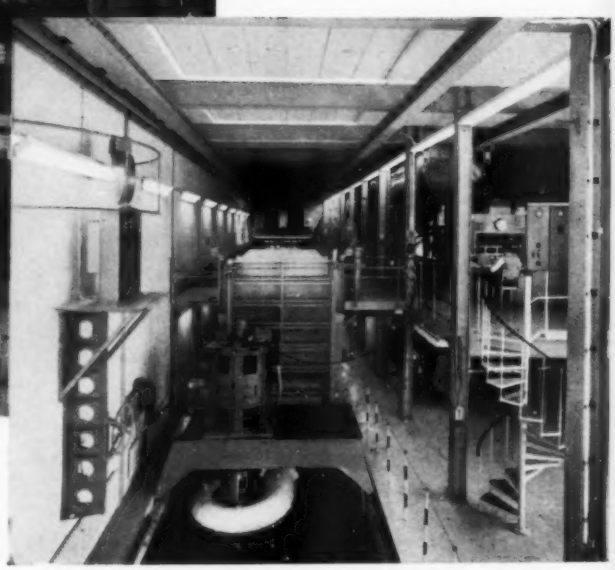
CIVIL ENGINEERING CONTRACTORS

EDMUND NUTTALL SONS & CO. (LONDON) LTD. 22 GROSVENOR GARDENS, LONDON S.W.1 PHONE: SLOANE 0036

KMW tu

Runner for one of the Harrsele turbines.

The large flume shown below is the dominating feature of the KMW turbine laboratory.



Hydro-electric development on the Ume River in northern Sweden has been the most concentrated in the country. The 350 m (1,150 ft) of head available will be utilised by no fewer than 13 plants. It is estimated that, when fully developed, the river will provide an annual output of 8,100 million kWh. The total sum invested in these plants is expected to amount to about £100 million.

Seven of the 13 stations on the Ume River will have KMW turbines with a total installed rating of roughly 765,000 h.p. The turbines for a further two stations, with a total rating of about 200,000 h.p., are being supplied by a KMW subsidiary company, Finshyttans Bruk.

The first-rate laboratory and workshop facilities at KMW have been decisive factors in the choice of KMW turbines for the stations on the Ume River.

High precision measurements

In the KMW hydraulic laboratory, which is recognised as one of the best equipped in the world, research work is not confined to the conventional types of water turbines, but also embraces bulb units and reversible pump turbines.

A qualified laboratory staff of technical specialists provide the data required in the various stages of turbine planning, design and manufacture. The equipment they have at their disposal also permits high precision measurements of turbine performance.

Turbines For Power Stations On The Ume River

Exceptional production facilities

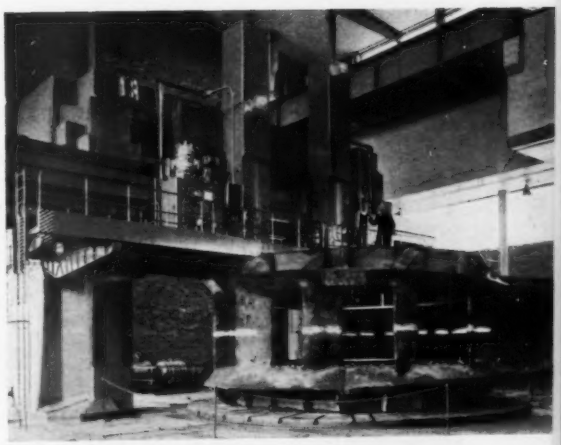
The workshop equipment at KMW is the most modern available and includes specialised machines for large turbine parts, such as a vertical boring mill which can accommodate a 125-ton workpiece 15 m (50 ft) in diameter, profiling machines and boring machines with 200 mm ($7\frac{7}{8}$ in) spindle diameter and 11 m (36 ft) longitudinal traverse.

A new modern plate shop and foundry, the largest of their kind in Scandinavia, are also essential parts of the unique production facilities offered by KMW.

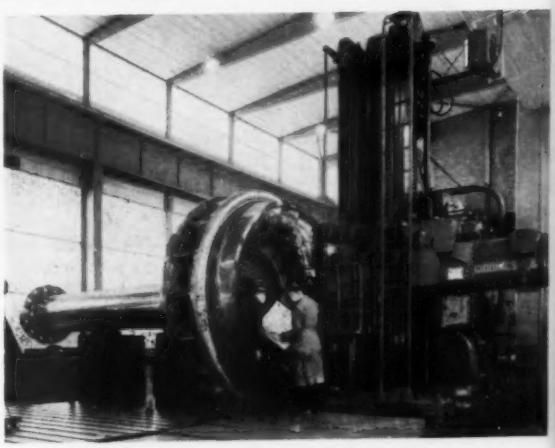
KMW turbines at stations on the Ume River

Station	Type	Total output	Head		Speed
		h.p.	m	ft	r.p.m.
Umluspen ...	2 Kaplan	110,000	30·0	(98)	150
Stensele* ...	1 Kaplan	67,000	18·3	(60)	93·6
Grundfors* ...	2 Kaplan	128,000	34·0	(112)	150
Rusfors	1 Kaplan	55,000	11·7	(38)	71·4
Bålforsen ...	2 Kaplan	110,000	31·0	(102)	150
Bjurfors Övre	3 Kaplan	57,000	11·1	(36)	107
Bjurfors Nedre	3 Kaplan	102,000	19·5	(64)	125
Harrsele ...	3 Francis	264,000	52·6	(173)	125
Pengfors ...	3 Kaplan	66,000	14·7	(48)	125

* Supplied by a KMW subsidiary company, Finshyttans Bruk.



Machining a stayring in a vertical boring mill which can accommodate components up to 15 m (50 ft) in diameter.



A Francis runner in one of KMW's large boring machines.

AB KARLSTADS MEKANISKA WERKSTAD
KARLSTAD - SWEDEN

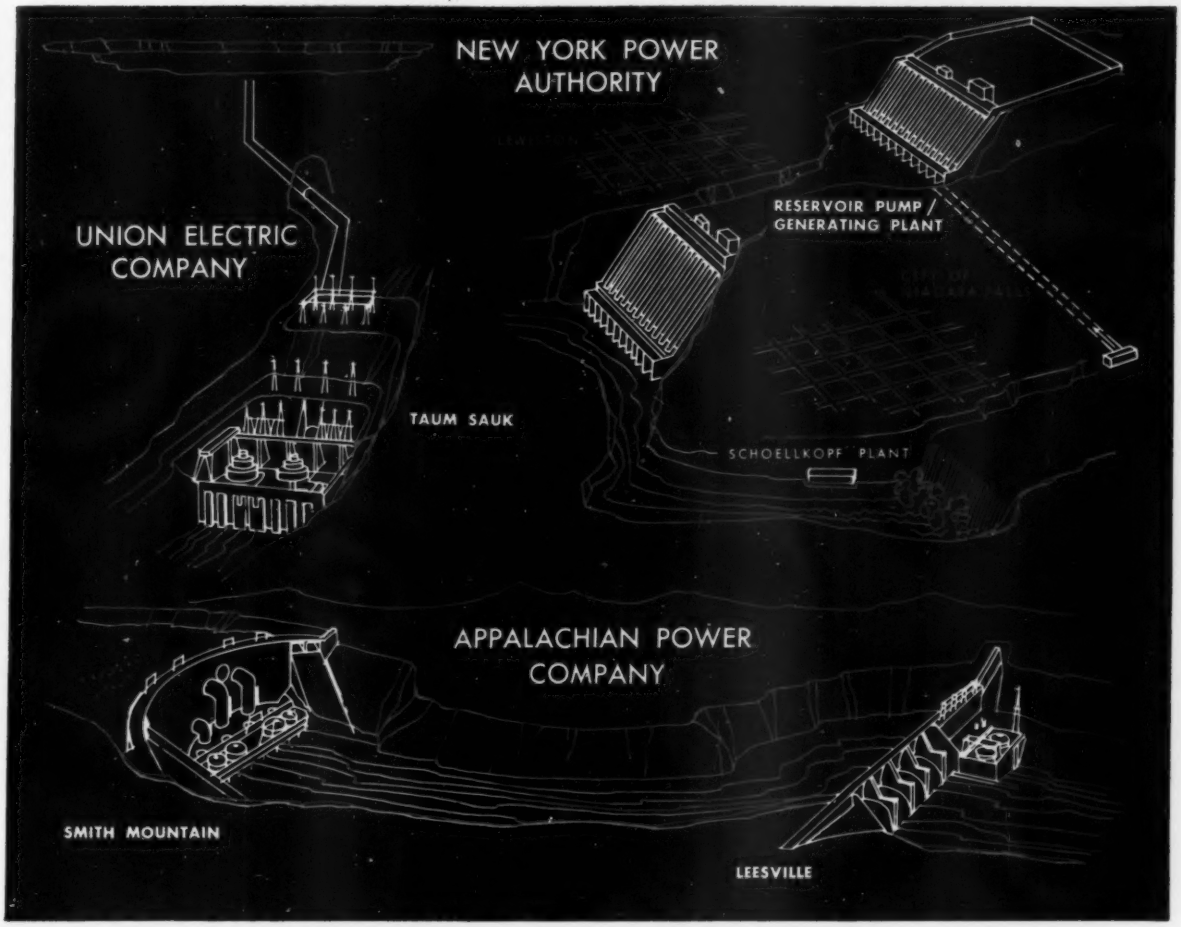
KMW

Penstocks, pressure shaft linings,
Substation steel structures
Gantry and overhead travelling cranes
Pylons, water gates

Pressure test and Electric Strain Measuring carried out on the Manifold of the Koyna Power Station (Maharashtra State, India). Test pressure 1420 psi. Diameters 8′ 6″ / 2 x 6′. Thickness 1″ 27/32 and 1″ 37/64. Weight 40.5 tons.

GIOVANOLA Monthey - Switzerland

ALLIS-CHALMERS



Just what you'd expect from the pumped-storage pioneer:

first in all three

Pumped-storage power projects now under construction in this country all rely on Allis-Chalmers reversible pump-turbines. In fact, A-C is the only builder of complete reversible pump-turbine equipment!

First in boosting existing hydro at Niagara Reservoir pump/generating plant! This pumped-storage project will capitalize on the hydro-electric power potential of Niagara River without adversely affecting the scenic beauty of the Falls. Largest project of its kind, this installation will include 12 reversible pump-turbines with motor-generators . . . all designed and fabricated by Allis-Chalmers. As a turbine, each unit is rated 28,000 hp under 75-ft net head; as a pump, 3,400 cfs at 85-ft total head.

First in pure regeneration — at Taum Sauk! . . . also to have the largest-capacity hydro units ever built. Allis-Chalmers will supply two 175,000 kw reversible pump-turbines, each with a capability exceeding 300,000 hp under 800-ft head. (Pure regeneration installations need only a water supply to replace evaporative losses, so a creek is ample. Even a hill is unnecessary: the pool can be underground, in an abandoned mine shaft, for example.)

First in run-of-river — at Smith Mountain! This new project involves reservoirs at two successive levels, the lower dam forming a tailrace pool at the upper dam for two A-C reversible pump-turbines, each rated 87,000 hp at 180-ft head. Conventional hydro-generating units will also be installed — two higher-head units at the upper dam and two lower-head units at the lower dam.

For complete information on pumped-storage, hydro-generating equipment or other components for water control, contact your nearby A-C office. Or write to **Allis-Chalmers,** *Hydraulic Division, York, Pa.* A-1385

Outside United States contact Allis-Chalmers International, or in Canada, contact Canadian Allis-Chalmers

We design and build for Hydroelectric Power Plants

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Laksapana Power Plant (Ceylon) : Penstocks

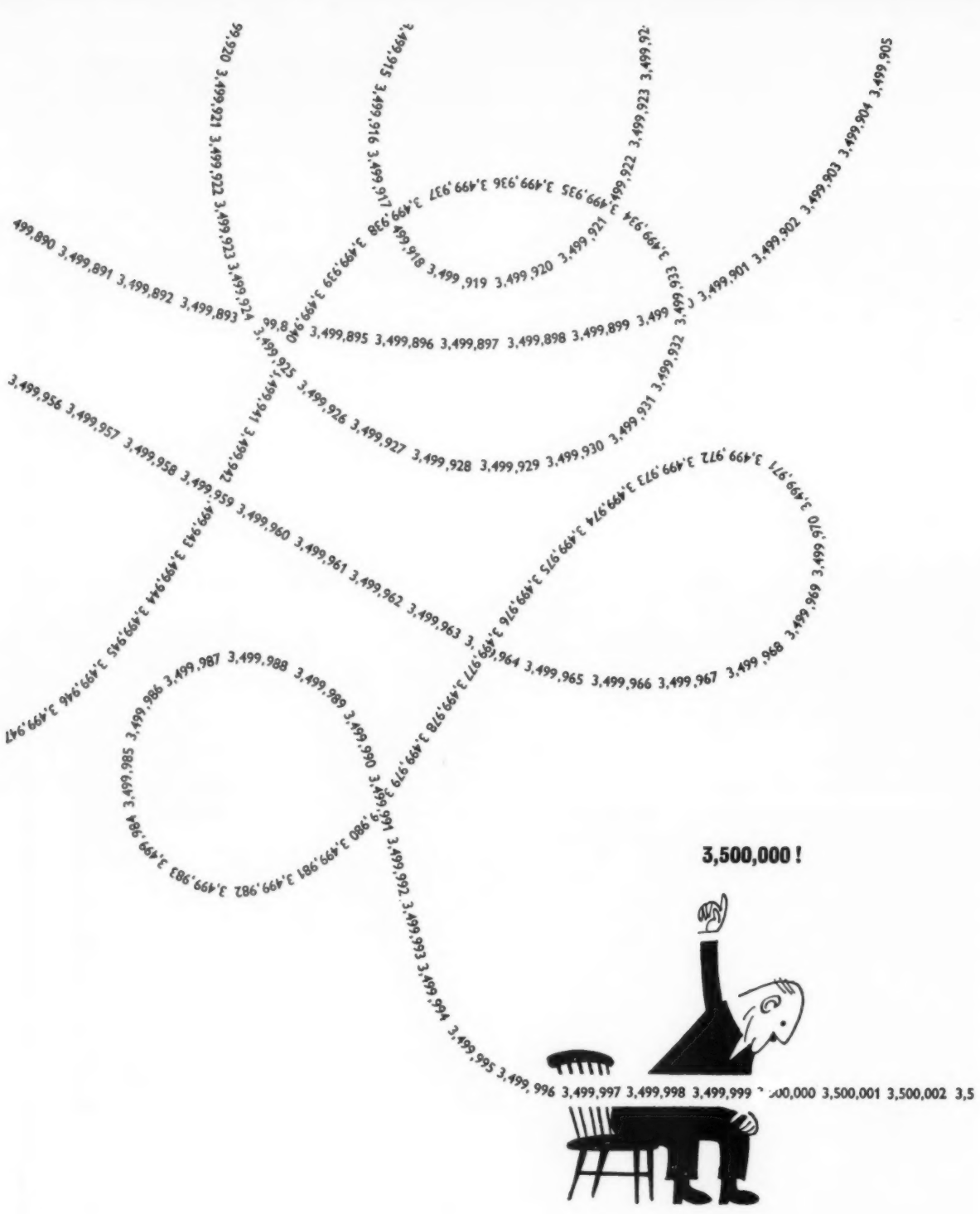
Serre-Ponçon Dam Project : concrete gallery extending over 7,000 ft.

Laksapana Power Plant : Two 16,100 kW Pelton units under erection

CONSTRUCTION AND ERECTION OF ANY HYDRAULIC POWER PLANT EQUIPMENT

Penstocks, Valves, Turbines, Alternators, Electric Switchgear, Transformers, etc...

CIVIL ENGINEERING WORK



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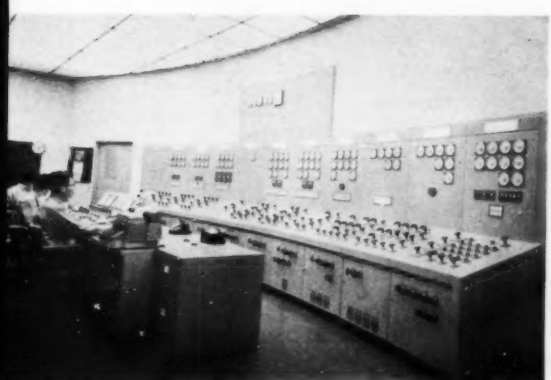

Switchboard installed at the Miboro Power Station, Central Japan.

Hitachi has recently completed two 137,500 kw/125,000 kVA hydraulic turbines and generators for the Miboro Power Station in Central Japan.

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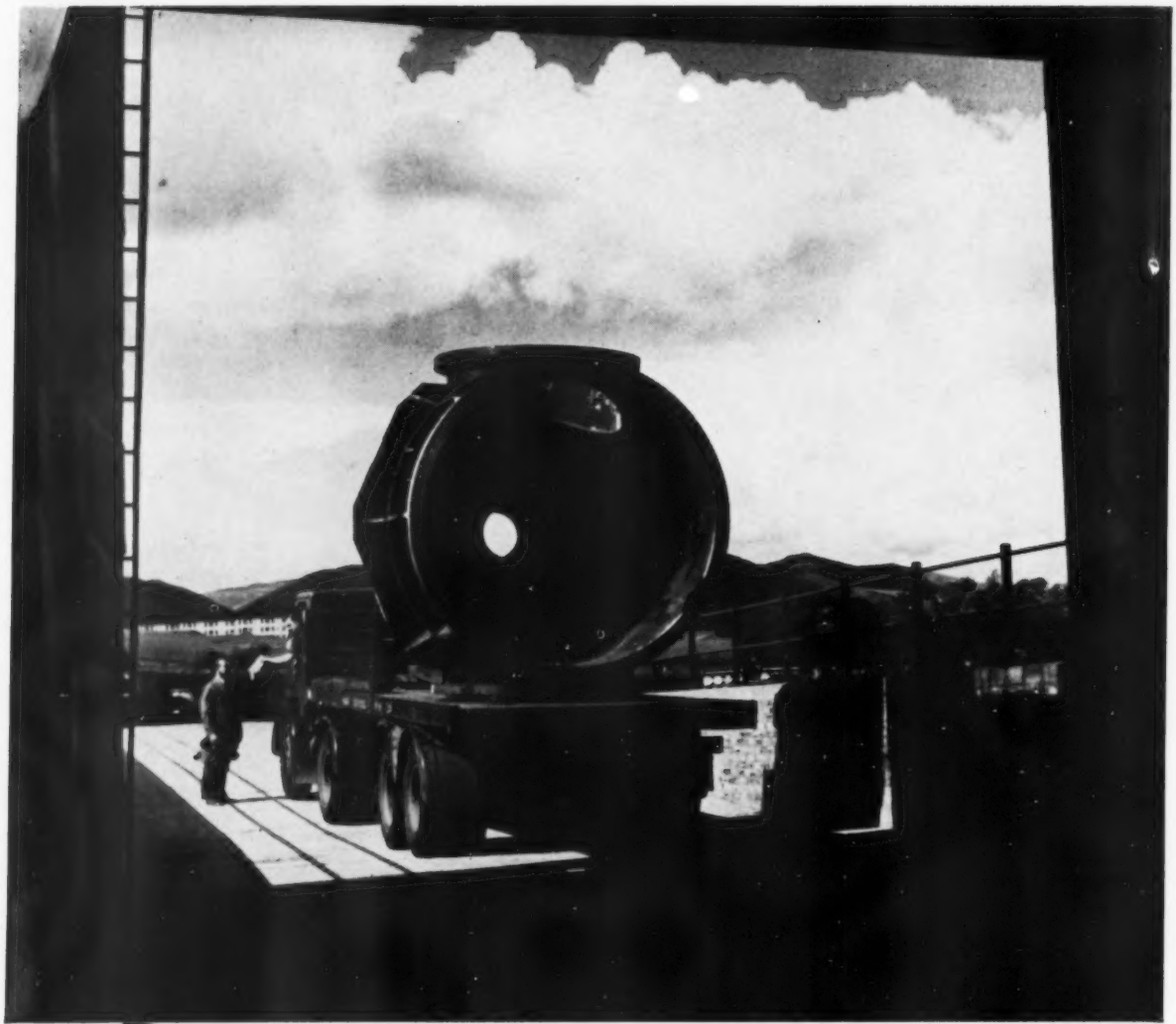

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Volume 13 Number 11

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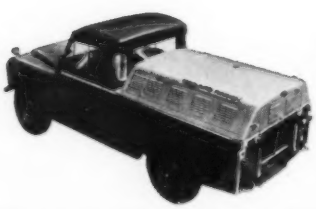

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WATER POWER

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Economics of Tidal Power

A RECENT visit to the Rance tidal-power scheme in Brittany gave welcome evidence that the work is now firmly progressing, after the many hesitations since the days when the scheme was first proposed in a practicable form. On the left bank of the River Rance at La Brebis point, the lock for the passage of the small vessels that need to navigate the river as far as Dinan is already constructed, while on the right bank, at La Briantais point, a large cofferdam enclosure is being constructed so that the six sluice gates, each 15 m wide and 10 m high, which will play an integral part in the operation of the scheme, can be constructed under dry condition. In St. Malo harbour a large caisson was seen in an almost complete condition ready to be towed the short distance to the tidal-power dam site so that divers could descend within it and start on foundation work.

It will be recalled from previous articles in WATER POWER that the scheme provides for 24 bulb sets of 10 MW each, and that by using the characteristic feature of reversibility of both pump and turbine, the scheme can be made to generate power at almost any state of the tide. The designers say that during the 1,200 hours of high demand in the three winter months of December, January, and February, an average output of 96·8 MW can be given to the system whatever the state of the tide, providing pumping energy has been made available at some other period of the 24 hours, and that during the 300 hours in the winter months when the actual peaks occur, the plant can produce 194·5 MW, again irrespective of the state of the tide.

Our visit to the scheme was made in conjunction with the Supply Section of the Institution of Electrical Engineers, and it was interesting to observe the reactions of distinguished engineers in the supply industry in Great Britain to this fascinating proposal to harness the tides. British supply engineers tended to think that the whole project was somewhat costly, since at an estimated figure of about 400 million New Francs, or about £30 million, the cost per kilowatt of what they regarded solely as firm power—the figure of 96·8 MW—was something over £300; and this they compared with the present-day cost of thermal power stations in England of between £45 and £50 per kilowatt, or the nuclear-power-station cost of something in the region of £100 per kilowatt. Water-power comparisons do not come easily to British engineers, or indeed to engineers in other countries with predominantly thermal power-generating systems; but those who were familiar with such figures said that £300 per kilowatt of firm power was a very high price to pay even for a conventional hydro-power station. However, considered from the point of view of the peak power, when 194·5 MW could always be made available, the cost figures were obviously halved. They then took on some sort of parity with general hydro-electric costs for a scheme of this size.

The argument then turned to the value of peak power, and soon it became obvious that there were many viewpoints as to the additional value to be placed on units available only at peak periods. In America, in the thermal power field at any rate, there has been much discussion in recent years as to the desirability of building plant solely for peak generation purposes; and the arguments supporting this view have contained many elements leading to the supposition that peak power is worth as much as three times power generated at off-peak periods. In consequence, the value to be attributed to the Rance tidal-power scheme is not altogether easy to assess.

Few thermal power-station engineers take into account the very long life that can be attributed to properly maintained hydro-electric installations of all kinds, and the Rance scheme, although it deals with sea water instead of the fresh water normally used in hydro-electric projects, is not likely to have a shorter life than any other hydro scheme. We saw the immense care the French engineers had taken to test out materials such as bronze, stainless steel, various kinds of paints and coatings, and other anti-corrosive devices, to ensure that corrosion problems in connection with the bulb generators and their ancillary equipment would not give rise to undue trouble. The

division of the generating plant into 24 units of the relatively small size of 10 MW each means that to take one or more units out of commission for maintenance purposes will only reduce the power output by a moderate amount, and thus there is no major problem in ensuring that the scheme will continue to operate for many generations.

In connection with the long life of hydro-electric equipment, we recently visited, once again, the "old" power station at Trollhättan in Sweden, where 13 units of 10 MW each were installed in 1910, and now, 51 years later, all of them are still operating perfectly satisfactorily and must have long since been written down to zero in the books of the Swedish State Power Board. There is no reason why they should not continue to operate for many years to come, and our own inspection of some of the internal parts of a set under maintenance this summer showed that the state of the mechanical parts, as well as of the electrical equipment, is as perfect as would be the case if a set built in much more recent times were opened up for examination.

Pumped storage is very much in the hydro-electric news in many parts of the world, and just as in the case of the early nuclear power stations, there has been a mixture of admiration at the audacity of the design and recognition of the brilliance of the designers' ingenuity, coupled with apprehension as to the capital cost. Here, however, there is additional room for argument, since no pumped-storage station, whether of the tidal or of the conventional type, can produce power at all times. The tidal scheme comes nearer to this greatly desired characteristic, since energy is brought in from the sea instead of from the network alone; but if it is to be of real service to the operating engineers, as in the case of the Rance project, it too must borrow energy. There is still room for research into the relative costs of energy at on-peak and off-peak periods in relation to given system conditions, because until this factor is capable of logical and irrefutable exposition there must always be some doubt about the economics of a particular pumped-storage scheme, whether tidal or not.

It will be about five years before the first units of electricity are generated by the Rance scheme. By that time the French power-generating system will be approaching double the size it is now, and thus the full output of 240 MW will assume rather small proportions in relation to something like 50,000 MW, which may be the total generating capacity in France at that time. This will mean that the operating engineers of Electricité de France can perhaps more boldly experiment with the Rance scheme and can undoubtedly provide valuable cost data from its operation. It will be small enough in relation to the whole system to be operated not only for its commercial contribution to the demand but also for purely experimental purposes. If the Rance project is proved to be successful, and if engineers can be convinced the cost of energy from such projects is reasonable and has value to the system by working happily in conjunction with thermal, nuclear and other hydro-electric plant, then we may look towards further very large tidal-power projects being proposed and ultimately executed. When the tides can be made to yield hundreds of thousands of megawatts—and there is no technical reason why this should not happen—they will take their place as a major source of energy.

Kariba Dam Repairs

IMPRESIT, the main contractors for the construction of Kariba dam, have submitted an estimate to the Federal Power Board for buttressing the south flank of the dam wall. It is understood that the work will be carried out by these contractors, bringing the total cost of the first stage of the project to £78,000,000. This figure is still comfortably inside the original estimate of £79·4 million in spite of the additional expenditure incurred.

A Federal Government committee has been set up to examine the distribution of electricity in Southern Rhodesia, to introduce any necessary improvements and to make the best use of Kariba power.

FAO to Investigate Kafue

EXPERTS from the United Nations Food and Agriculture Organisation in Rome are expected in Northern Rhodesia to start a comprehensive survey of the Kafue Basin area. The principal object is to examine the Kafue River and its main tributaries in order to put the waters of the river to greater use. Although the potential of the Kafue Basin is not fully known it is believed to be great, and another of the objects of the survey is to find the "fixed assets" of the area. However, it is known that there were 60,000 acres of first-class soil, huge areas of land suitable for tobacco growing and large areas of good pasture land. The Kafue Basin survey will take four years and will cost nearly £500,000. The Northern Rhodesia Government will pay half the cost and the United Nations through the FAO will supply staff, costing an equivalent amount.

It will be recollected that a report embodying proposals for the power development of Kafue River was presented by Sir William Halcrow, Mr. Harold Gourlay, Mr. C. H. Pickworth, and Mr. Geoffrey Kennedy in 1953.

Pump-Turbines for Cruachan

WE are now able to supplement the information given briefly in our September issue about the pump-turbine sets ordered by the North of Scotland Hydro-Electric Board for Cruachan. This installation will make history, because it is believed that it will have the highest head in the world for which reversible pump-turbines are being used. The head, in fact, is well over 1,100 ft, whereas, according to our records, the nearest figures are 850 ft at Providenza and 800 ft at Taum Sauk.

Four 100-MW units have been ordered, two from Boving & Co. Ltd. and Associated Electrical Industries Limited, and two from The English Electric Co. Ltd. The Boving machines are designed for a net turbine head of 1,160 ft and a maximum pumping head of 1,207 ft. As a turbine each machine will develop 140,000 h.p. at a net head of 1,125 ft, and as a pump will require 150,000 h.p. Extensive model tests have been carried out to obtain the best compromise of good efficiencies in the turbine and the pumping phases, and particular care has been taken in the design of the movable guide vanes and fixed stay vanes as well as in the design of the runner. The clearance between the runner and the speed ring is kept very fine in order to reduce leakage, and a special labyrinth design has been adopted. The runners will be

integral castings in 13% chrome steel. Rotary-type inlet valves will be used, sealing in the closed position being obtained by means of a sliding steel cylinder. These machines will be built mainly at the works of John Brown & Co. (Clydebank) Ltd.

The AEI generator/motors will run at 500 r.p.m. Low-loss cold-reduced sheet steel will be used for the stator cores, and the stator coils will be insulated with mica tape bonded with a modified epoxy resin. These sets will be provided with a pony motor for starting in the pumping phase.

The English Electric pump-turbines have been developed at Netherton and Rugby in collaboration with Sulzer Brothers, Winterthur. They will be rated at 142,000/136,500 h.p. per unit, and, complete with governors and main valves, will be manufactured mainly at the Scotstoun works of Harland & Wolff Limited.

The Cruachan pumped-storage station will be the major installation of the Board's Loch Awe scheme, which will also have two conventional hydro-electric stations at Inverawe and Nant. The civil-engineering consultants for Cruachan are James Williamson & Partners and the mechanical and electrical consultants Merz & McLellan.

A note on the civil-engineering contract for Cruachan underground station was published last month.

Stalingrad Station Officially Opened

IN September Mr. Khruschev officially opened Stalingrad station, which is the seventh to be completed on the Volga-Kama network. It is powered by 22 Kaplan turbines, operating under 22-m head, of the same design as the 20 machines installed at Kuibyshev, but the nameplate rating has been increased from 105 MW to 115 MW, giving an aggregate capacity for Stalingrad of 2,530 MW. This is believed to be the largest hydro-electric station in the world, but still larger stations are under construction or planned in Russia; Krasnoyarsk, now under construction, will have a capacity of 3,600 MW and will house twelve 300-MW machines—believed to be the world's largest. A 4,500-MW station is under construction at Bratsk, and a 5,000–6,000-MW station is planned on the Yenisei.

A 500-kV transmission line will carry the power from Stalingrad to Moscow, and another line, to run possibly at 800 kV, is planned to the Urals.

World Bank Annual Report

THE Sixteenth Annual Report, for 1960–61, issued by the International Bank for Reconstruction and Development records that 27 loans totalling US $610 million were made during the year, of which eight loans amounting to $125 million were for power development. In Europe two loans were made, one of $25 million to Norway for Tokke II and III, and one of $30 million to Yugoslavia for a 216-MW development on the Lika river. In Asia, Ceylon has benefitted by a loan of $15 million for a 50-MW hydro-electric plant at Norton Bridge and for a 25-MW steam set for Colombo; and Japan has received $12 million for thermal plant for the Island of Kyushu. In Africa, Uganda has received a loan of $8·4 million to develop the Owen Falls transmission network. Three loans have been granted to Latin-American countries. Colombia has received $22 million for the second stage of the Guadalupe hydro-electric development; Costa Rica has received $8·8 million for a new plant on the Rio Macho; and El Salvador $3·84 million for a second power plant on the Lempa river.

The First Annual Report has also been issued of the International Development Association, which is affiliated with the World Bank but is a separate entity established to provide capital on more liberal terms, and to finance a wider range of projects, than the Bank. Its loans for its first year of operation do not enter into the power field.

Norwegian Hydro-Electric Capacity

AT the Annual Meeting of the Norwegian Hydro-Electric Association it was announced that in 1960 there had been a net gain of 441 MW, bringing the total capacity of Norwegian hydro-electric stations up to 6,335 MW. In the years up to 1965 a further expansion of 2,202 MW is planned. Investment in the electricity-supply sector in 1960 amounted to Kr. 818 million (£40,900,000) as against Kr. 787 million (£39,350,000) in both 1958 and 1959.

International Conference on the Physics of Semiconductors

THE Institute and Society on behalf of the International Union of Pure and Applied Physics, and the British National Committee for Physics is arranging an International Conference on The Physics of Semiconductors, which will be held at the University of Exeter from 16–20 July, 1962. The Conference is planned to follow the previous sequence of Conferences on the physics of semiconductors, which were held in Reading in 1950, Amsterdam in 1954, Garmisch in 1956, Rochester in 1958 and Prague in 1960. Accommodation will be provided in Halls of Residence at the University. Further information regarding the Conference may be obtained from the Administration Assistant, The Institute of Physics and The Physical Society, 47 Belgrave Square, London, S.W.1.

Multipurpose Project for Montana

A CONTRACT for the construction of the Yellowtail dam and power plant on the Bighorn River in Montana, U.S.A., has been awarded to a consortium comprising Morrison-Knudsen Co. Inc., The Kaiser Company, Perini Corporation, Walsh Construction Company, and F. and S. Contracting Company. The contract is valued at approximately $40 million, and construction is scheduled to be completed by October 1966.

The project is a multipurpose one, and the reservoir capacity of 1,375,000 acre-ft will be divided between flood-control, irrigation and power requirements. The dam is to be concrete arch, 520 ft high above the foundation and with a crest length of 1,450 ft. In addition there will be an earthfill afterbay dam, with a concrete ogee spillway section, situated some two miles downstream of the main dam. Irrigation-canal headworks will be situated on the right bank at the lower site, and irrigation water will also be pumped from the afterbay.

The power station is to be situated at the toe of the main dam, and will have four 50-MW vertical-shaft alternators coupled to Francis turbines. The

penstocks, which will pass through the dam, will each have a diameter of 12 ft. In addition to irrigation outlet works in the main dam, there is to be a 32-ft diameter spillway tunnel through the left-bank abutment, which will have a maximum discharge capacity of 173,000 cusecs.

Irish Annual Report

THE 34th Annual Report of the Electricity Supply Board of Ireland for the year ending March 31, 1961, shows that it was a good year for hydro-electric generation, owing to generally above-average run-off. The hydro output rose from 747 GWh in the previous year to 932 GWh, out of a total production of 2,260 GWh. The increase in total generation was 7·9% over the previous year, and the average annual load factor was 47·8.%

Although an expansion of generating capacity is envisaged over the next few years, no new hydro stations are planned in the immediate future; nevertheless, work has continued on the investigation of 17 undeveloped rivers. The Board also has under consideration the construction of a new 220-kV transmission network.

We should like to congratulate the Electricity Supply Board on the admirable presentation of their report, and the valuable data on plant performance and other technical matters given in the appendices. Much of this material should prove of wide interest.

Sierra Leone Hydro-Electric Possibilities

A TEAM of three German specialists is reported from Freetown by Barclays Bank D.C.O. to have arrived in Sierra Leone to investigate the possibility of building a hydro-electric power station. The team expects to visit the Bombali, Port Loko and Tonkolili districts, where they will inspect the Mabali, the Little Scaries, Seli and Pampana Rivers. They will also inspect the Bumbuna Valley near Magburaka.

Scottish Power Inquiry

EVIDENCE given to the Mackenzie Departmental Committee on the future of the North of Scotland Hydro-Electric Board indicates some division of support within Scotland itself for the continuity of Board operation. Interested bodies have released details of their evidence to the committee, indicating their attitude, and in general the views follow the expected pattern. The Advisory Panel on the Highland and Islands supports the continuance of the Board and indeed urges an extension of powers so that the Board can still further stimulate industrial and social progress. The Scottish Trades Union Congress has deplored any attempt to reduce the scope or activities of the North of Scotland Board. Any diminution of responsibility or power would be a tragedy for the Scottish highlands, in their opinion. The Edinburgh Chamber of Commerce is less actively in support of the Board although it pays tribute to the massive work already done. Edinburgh view is that the time might now be ripe to consider the whole situation in the light of the low-cost power production situation in the industrial belt of Scotland. The money that might be spent on hydro-electric power projects might be equally effectively spent on road and bridge construction which are as vital in the highlands as elsewhere. One point made by the Chamber is that the alleged amenity losses arising from construction of dams is negligible in comparison to the damage caused to amenity by the ever increasing number of overhead pylons carrying power lines. The full findings of the Committee remain to be released.

Latin-American Power Seminar

THE First Latin-American Seminar on Electric Power, convened in Mexico City recently, stressed the need for an intensive programme of electrical development during the next decade. In 1959 the production in Latin America was 62,000 GWh, corresponding to an output per capita of only 315 kWh. This is only 44% of the world average of 720 kWh. To make good the deficit and to avoid impeding economic development it was estimated that production should be increased to 200,000 GWh in 1970. This would entail nearly tripling the installed capacity from 16,000 MW to 46,000 MW.

Electricity Supply in Portugal

HEALTHY progress in electricity supply in Portugal continued to be maintained during 1960, as is disclosed by the annual volume of statistics published by the Ministério da Economia, although the rate of increase, both in installed capacity and in production, was slightly less than in preceding years. Total installed capacity at the end of the year was 1,335 MW, of which 1,085 MW was hydro-electric. This increase was due almost entirely to the commissioning of Miranda station, of 52 MW capacity, on the Douro; the installed capacity of thermal stations actually fell from 265 to 250 MW.

Total production for the year was 3,263 GWh, an increase of 9% over 1959; hydro-electric production was 3,105 GWh, an increase of 8·4%, and thermal production 159 GWh as against 130 GWh in the previous year. This increase in thermal production, which reverses the trend for previous years, arose because the Tapada do Outeiro 50-MW station of Empresa Termoeléctrica Portuguesa, came into full service after efficiency tests had been carried out in 1959.

Reservoir capacity remained unchanged during the year, but the energy stored fell from 980 to 660 GWh, due mainly to reduction in storage in Venda Nova and Caniçada reservoirs, and to a lesser extent Salamonde. The secondary reservoir system was maintained at the end of the year at virtually full storage.

Record Turbine Deliveries

KARLSTADS MEKANISKA WERKSTAD report that this year they will be establishing a new record for turbine deliveries. No less than 17 new KMW turbines, with a combined output of 890,000 h.p., will be put into operation in 11 stations, including three units for Chile, two for Egypt and one for Norway. The largest unit is a 147,000-h.p. 190-m-head Francis machine for Stalon. Amongst new orders received is a Francis unit for Gallejaure rated at 175,000 h.p. at 78-m head, which will be the largest machine yet built by the company. Another notable turbine will be a 68,000-h.p. Kaplan unit for Krokströmmen. This will operate under a head of 59·5 m, which is believed to be the highest head for a Kaplan machine in Scandinavia.

Fig. 1. General view of Fort Peck power plant

Harness for America's Missouri River

The overall development plan for the Missouri River is outlined and the chain of plants on the main stem of the river is described

By BRIG.-GEN. W. R. SHULER*

AMONG the large river systems of the United States of America, the Missouri has the distinction of being the longest single river in the nation. Rising on the eastern slopes of the Rocky Mountains, it courses 2,460 miles to join the mighty Mississippi near St. Louis, Missouri.

Length is not the Missouri's only claim to distinction. It is a meandering stream of unstable banks and heavy sediment-carrying capacity which in its natural state produced widespread and destructive flooding. It was named by American Indian tribes, the word Missouri being interpreted to mean "Big Muddy, a colloquialism still frequently used.

The drainage basin of the Missouri and its numerous tributaries (Fig. 2) occupies an area of some 530,000 sq miles, a small segment of which extends across the border into Canada. It encompasses all or parts of ten states. This includes the Northern Great Plains area, a region of quite variable climate and rainfall. Its economy is largely agricultural and its population relatively small in the north and west portions.

* Missouri River Division Engineer, US Army Engineers.

Because of limited precipitation in the western part of the Missouri Basin (generally 8–16 in annually), extensive irrigation has been developed. Water use has been the subject of considerable State and Federal legislation, inter-state compacts and other regulatory action for more than half a century. But it was not until the early 1940s that a comprehensive plan for control of floods and multiple-purpose use of water began to emerge in this large midland section of the United States. A prolonged drought in the 1930s and destructive floods in the early 1940s gave impetus to the popular movement for a planned programme of river controls in the Missouri Basin.

It was natural that the demand for electric power in this region was less advanced than in older settled and industrialised portions of the United States, such as the industrial East, the Great Lakes region, the Ohio Valley and the West Coast. Much of it was, and continues to be, farm and ranch country. However, coincident with the initiation of a major flood control and river-development programme authorised for the Missouri Basin by the US Congress in 1944, the upper Basin rapidly became a power-hungry

Fig. 2. Map of the Missouri Basin showing main-stem and tributary storages

region. Contributing factors were the rapid mechanisation of the farms and ranches, growing development of pump irrigation, and a sudden boom in air conditioning of homes, businesses and service institutions.

Hydro power thus came into consideration as part of the economic justification for the building of a system of large dams and reservoirs on the Missouri River and some of its tributaries. Congress, in the enabling legislation, recognised four basic purposes to be served by the Missouri Basin programme. These were flood control, irrigation, improvement of the lower Missouri for navigation, and hydro-power production. Other beneficial services included public recreation, fish and wildlife conservation, municipal and industrial water supply, and stream-pollution abatement.

The overall Missouri Basin plan provides for some 100 dams and reservoirs of varying size on the main stream and tributaries. The main stem system consists of six reservoirs extending along the Missouri from the State of Montana to the State of Nebraska. They are the Fort Peck dam in north-east Montana, Garrison dam in North Dakota, Oahe, Big Bend, and Fort Randall in South Dakota, and Gavins Point on the South Dakota-Nebraska border (Fig. 2). Other features of the programme include a bank stabilisation and navigation project extending 760 miles on the Missouri from Sioux City, Iowa, to the mouth; agricultural and municipal levees and floodwalls for flood protection; development of new irrigation projects encompassing about 4 million acres, and an extensive Federal hydro-power transmission grid.

Construction on this widespread programme has been under way for 15 years by Federal Agencies having responsibilities in water-resources control and development, in co-operation with the Basin states. Four of the presently authorised Missouri River main-stem dams have been completed, and the remaining two are under construction. In addition, 26 tributary dams have been essentially completed. Some 250 miles of levees and floodwalls have been constructed and the Missouri River bank stabilisation and navigation project is about 82% completed.

By established law and regulation, the US Army Corps of Engineers has responsibility for design, construction and operation of those projects primarily planned for flood control and navigation. The US Bureau of Reclamation of the Department of the Interior has charge of those planned primarily for irrigation. Thus, the main-stem system, with flood control and navigation as major functions, is being built by the Corps of Engineers, whereas the bulk of the tributary reservoirs fall to the Bureau of Reclamation. Close co-ordination is maintained by these two agencies.

Since the main-stem impoundments constitute the backbone of the Basin reservoir storage and regulatory system, this article deals largely with these projects, their functions and potentials for the safety and economic advancement of the region. Three of them rank among the largest earth dams in the world—Fort Peck, Garrison, and Oahe.

As shown in the profile drawing, Fig. 3, the main-stem reservoirs provide for multiple-purpose storage of water on a massive scale. Combined gross storage will approximate 75 million acre ft. This is the equiva-

lent of roughly three times the average annual flow of the Missouri in its natural state at Sioux City, Iowa, a control point below the lowermost reservoir.

The storage area in each reservoir generally is divided into three zones. The lower zone, labelled "inactive," is allocated to silt detention and power head; the middle zone to conservation storage for multiple uses, and the upper zone to be kept empty to catch flood flows. An exception is the Big Bend project which is designed primarily for power. It will have two storage zones, one for inactive storage and one for flood control.

Indicative of their size and functional importance to the overall Basin programme is the cost of these main-stem projects. The range is from $49 million for Gavins Point, the smallest in the chain, to $355 million for Oahe.

The four essentially completed and operating units of the main-stem system are Fort Peck, Garrison, Fort Randall, and Gavins Point. Oahe is about 65% completed, and Big Bend, latest to get started, was about 8% completed by the spring of 1961. On the basis of present schedules, the entire chain will be essentially completed and in operation by 1967. When completed and filled to normal operating levels, these reservoirs will be capable of storing maximum anticipated flood flows originating in the upper Basin. They will provide storage for irrigation of a million to a million and a half acres of land in the Dakotas, as planned by the Bureau of Reclamation. They will have hydro-power plants with a combined installed capacity of 2,048 MW, and provide regulated releases of water to maintain navigable depths on the Missouri River below Sioux City, during navigation seasons.

In the interim construction period the four operating main-stem projects are providing substantial public services, though subnormal run-off for several years has been a limiting factor. For example, in 1960 the four operating hydro-power plants produced 3,400 GWh of electricity. These four plants in early 1961 had a current installed capacity of 905 MW. Navigation releases during a 7¾-month navigation season in 1960 provided channel depths which made possible the movement of 1,430,000 tons of commercial freight on the lower Missouri.

These projects also gave a convincing demonstration of their flood-control effectiveness in 1960. In combination with downstream levees and channel controls, they sharply curtailed the damage potential of a spring flood resulting from heavy winter snow melt. These works reduced the damage potential of this flood from an estimated $200 million to actual damages estimated at $17 million.

The building of major dams and reservoirs on the Missouri's main stem involves some interesting and unusual design and construction features. The river, after it leaves the mountains, flows through alluvial plains which do not provide suitable foundations for concrete dam structures. All the main-stem structures are constructed of earth and relatively soft shales prevalent in the area. Intake structures, spillways, power plants and outlet tunnels are concrete and steel.

Fort Peck Dam

The Fort Peck project, first major dam on the Missouri, was built by the Corps of Engineers in the 1930s as a public works project. Fig. 1 shows the Fort Peck power plant housing three generators with a total capacity of 85 MW. A second power plant under construction at Fort Peck is scheduled for comple-

Fig. 3. Profile of main-stem dams, with storage data

Fig. 4. Aerial view of Garrison dam and power plant

tion in 1961, adding two additional 40-MW units. Fort Peck is the world's largest hydraulic-fill dam.

The earthfill dam measures 250·5 ft high, 21,026 ft long, has a maximum base width of 3,600 ft, and a width of 50 ft at the crest. The earthfill was placed hydraulically, four electrically operated suction dredge units being used. Each unit consisted of a dredge equipped with a cutter head and two pumps, a floating booster with two pumps, a land booster mounted on rails with one pump, and miscellaneous pipe and power-line pontoons.

The four dredges, constructed at the dam site, placed 122,178,000 cu yards of material from the commencement of dredging, October 13, 1934, to the end of dredging operations, November 5, 1939. The procedure was to pump the mixture of water-suspended sediments and gravels from borrow areas through 28-in pipelines to the dam. There the pipe openings were placed along the downstream and upstream edges of the dam where the coarser material was deposited to form the "shell," with the fine material being carried to the central core pool where it settled to form the impervious "core" of the dam.

Approximately 15% of the pumped mixture was solids. The excess water in the core pool was returned to the river, first over cascade-type spillways, and later by suction pumps. The material was pumped from the upstream side of the dam until the river closure was made in 1937, and downstream from that time. At one time the pipeline extended six miles downstream and the material was raised 200 ft above the river bottom.

The Fort Peck reservoir was designed to provide gross storage of 19,421,000 acre ft. At full capacity it has a water surface of 245,000 acres, has a shore line of 1,600 miles, is 189 miles long, has a clear width of 16 miles, and a maximum depth of 220 ft. Originally authorised and constructed as an aid to lower Missouri River navigation, this project has been incorporated into the comprehensive Basin plan and integrated with the other main-stem projects for multiple-purpose functions.

Garrison Dam

Next downstream in the Missouri River chain of main-stem dams is the Garrison project, located 413 river miles below Fort Peck. Its site was determined by the need to control the flow of the Yellowstone River, a major tributary which discharges into the Missouri near the Montana-North Dakota border. An aerial view of the completed Garrison Dam is shown in Fig. 4.

The structural design for Garrison marked a major change in placement of material as compared with Fort Peck hydraulic methods. At Garrison, Corps Engineers elected to use the rolled-fill method. Among factors leading to this decision was the type of material available for the embankment, which included a considerable volume of shale, known in this area as Fort Union shale, to be excavated from the spillway, power-

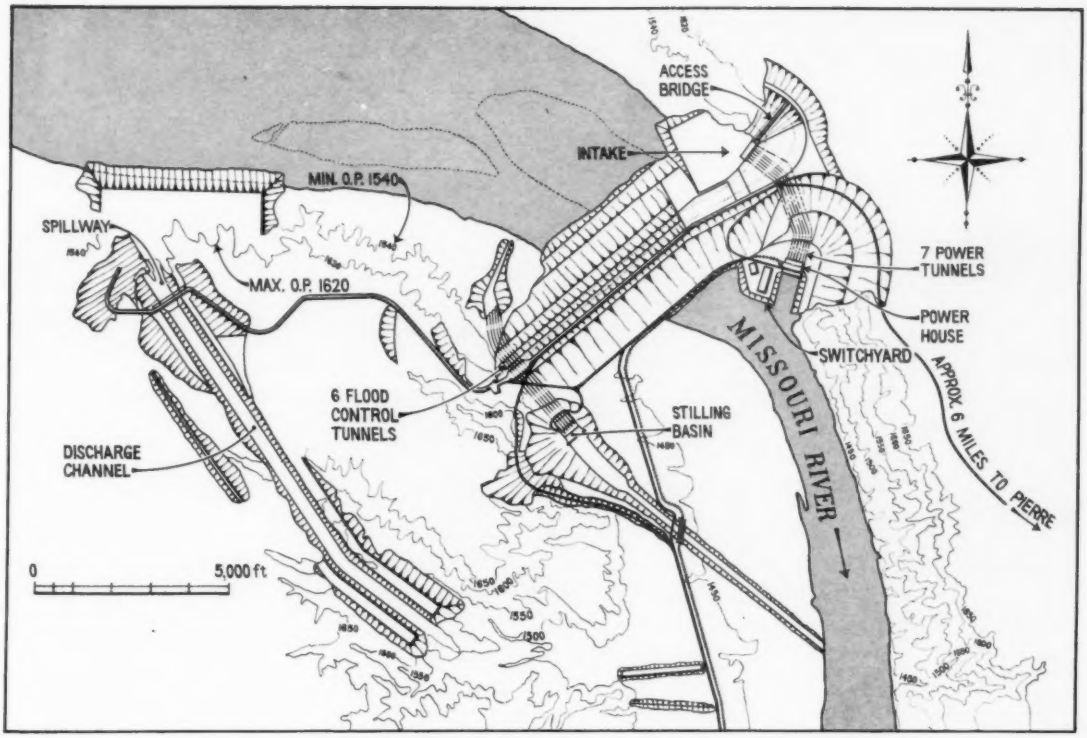

Fig. 5. General layout of Oahe dam

house, and intake areas. Another factor was the evolution in development of heavy earthmoving equipment. In the days of Fort Peck construction, dump-truck carrying capacity ranged from 5 to 7 cu yards; by the time Garrison got into construction dump-truck capacities had increased from 20 to 50 cu yards per load. Diesel-electric shovels with capacities up to 13 cu yards also had come into the picture.

The 66 million cu yards of material required for the Garrison embankment was placed almost entirely by end-dump and bottom-dump trucks. The material was placed in 8-in lifts, then compacted to about 6 in. A cut-off wall of steel sheet piling was driven up to 110 ft below the foundation to control under-seepage. An impervious earth blanket extends 1,250 ft upstream from the toe of the dam. This blanket, plus relief wells at the downstream toe, form the major under-seepage control measures. The upstream portion of the dam is of compacted impervious earth to seal off and hold back the reservoir water, while the downstream portion is semi-pervious with a pervious drainage blanket at the base to collect any seepage from below or from within the embankment and permit it to escape with-

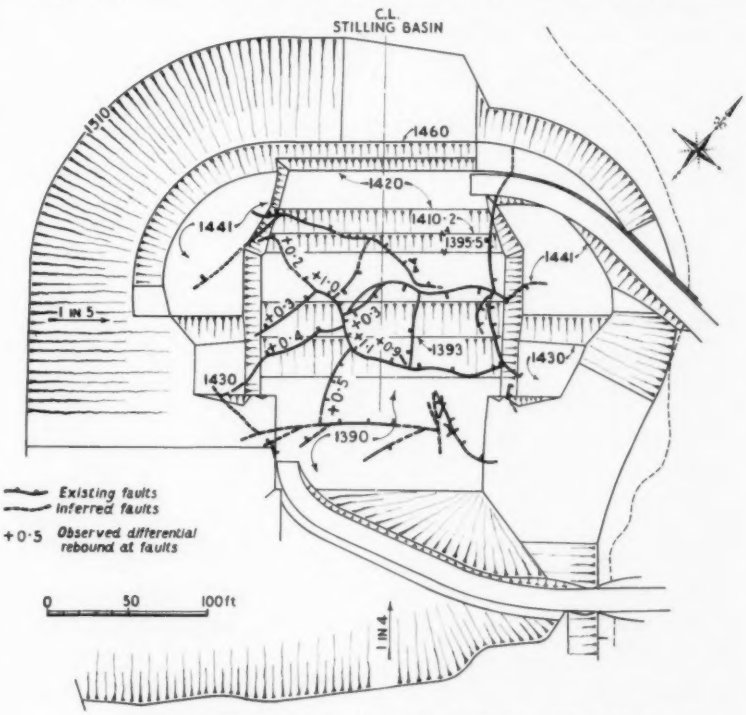

Fig. 6. Faults and rebounds at Oahe stilling basin

Fig. 7. Early model of the "Mechanical Mole" used at Oahe

out damage. The upstream surface is faced with approximately 650,000 cu yards of riprap to protect against wave erosion.

The gated chute-type spillway structure in the east abutment has a discharge capacity of twice the greatest flood of record at this point on the river. It has 28 tainter crest gates 29 by 40 ft, and its overall length is 1,336 ft.

Eight tunnels were driven through the west abutment for release of water in the operation of the reservoir for flood control, navigation, irrigation, power development and other purposes. The embankment is 12,000 ft long and rises 210 ft above streambed. Base width is 3,600 ft, narrowing to 60 ft at the crest.

Below the downstream portals of the five power tunnels is the power house, flanked by ten towering surge tanks. The power plant houses five 80 MW generators for a total installed capacity of 400 MW. All are now in operation.

While Garrison dam required less volume of material than the Fort Peck structure, its reservoir capacity is larger—24·5 million acre ft as compared with 19·4 at Fort Peck. It creates a lake which at maximum pool will extend 200 miles upstream.

Oahe Dam

Judged by some authorities to be the largest rolled-earth dam in the world, with a possible exception in Russia, Oahe Dam is located 432 miles downstream from Garrison near the South Dakota capitol, Pierre. Some statistical supports for this claim are its height of 242 ft; 90 million cu-yard volume of material in the embankment, 250-mile reservoir length, and cost estimate of $355 million.

In outward appearance the dam proper is generally similar to its upstream counterpart at Garrison. The embankment, now essentially completed except for completion of the rock facing, was constructed by the rolled-earth method. But in the case of Oahe, the power house and feeder tunnels are located on the left or east abutment, whereas at Garrison the location is reversed. Six flood-control tunnels are located in the right or west abutment at Oahe.

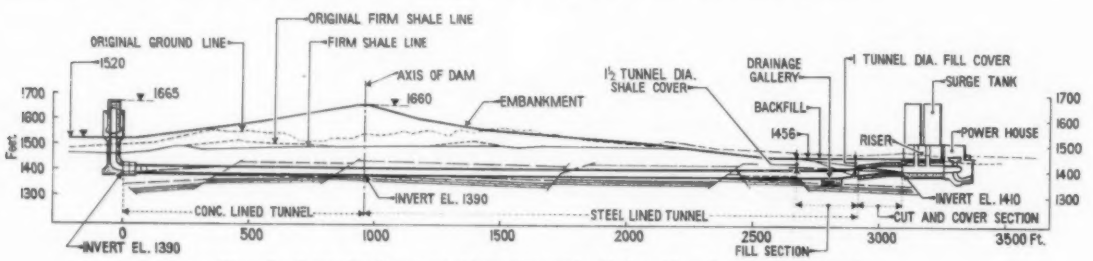

Fig. 8. Longitudinal section through Oahe No. 1 power tunnel

The general layout of Oahe dam can be seen in Fig. 5, and a longitudinal section through the No. 1 power tunnel is given in Fig. 8.

Major construction activity continuing at the Oahe project in the summer of 1961 included work on the large power plant (595 MW) and seven connecting power tunnels; on the spillway, and on relocations of highway and railroad bridges in the reservoir area.

Foundation material at the Oahe site consists principally of Pierre shale, a compaction type of clay-shale which disintegrates rapidly when exposed to air and weather. This shale, intersticed with slippery bentonite seams, posed some design and construction problems for the engineers. While test borings had indicated some faulting in the shale, actual construction operations revealed more extensive faulting. This instability was particularly pronounced on the east and west abutment areas where the bluffs drop off toward the river's floodplain. During excavation operations in the area of the intake structure on the west abutment, a large slide developed which provided some engineering headaches. As a corrective measure the side-slope gradient was flattened from 1 : 4 to 1 : 9 or 10. This necessitated a substantial increase in excavation on the slope, and relocation of the intake structure. The area is now stable.

Similarly on the east abutment, when excavation was under way for the power-house area, the east sidebluff developed a major slide a half mile long. This required design changes to flatten the slope. Modification of the original design required the excavation of over four million cu yards of additional material to stabilise the slope.

One of the interesting aspects of Oahe construction from a technical standpoint was the remarkable rebound characteristics of the shale material as experienced in the stilling-basin area after unloading by excavation, as shown in Fig. 6. The contractor was required to remove 200 ft of overburden to attain the design depth of the stilling basin for the flood-control tunnel outlets in the west abutment below the dam.

When this heaving action was noted by Corps geologists, immediate steps were taken to install mechanical measuring instruments. The vertical rebound was shown to be from eight to twelve inches over a substantial area of the stilling basin. Engineers considered this to be something of a phenomenon because of the eccentric movement along pre-existent fault planes. A further rebound of about 2 in was noted after placement of the reinforced-concrete slab over the stilling-basin area.

Meanwhile, based on the rebound data obtained, design modifications were instituted. The concrete slab was thickened to 8 ft over the entire stilling-basin area, whereas the original design had called for 5 ft in some areas and ranging up to 8 ft in others. A further step to ensure stability called for installing steel anchor bars to a vertical depth of 40 ft below the slab, spaced on 4½-ft centres. The bars were grouted in place. These remedial measures stabilised the stilling basin to the satisfaction of Corps Engineers and a board of private consultants.

Again, in the boring of the seven power tunnels in the east abutment, the faulted Pierre shale created some construction problems. The tunnels, ranging in length from 3,126 to 3,974 ft, were bored at a depth

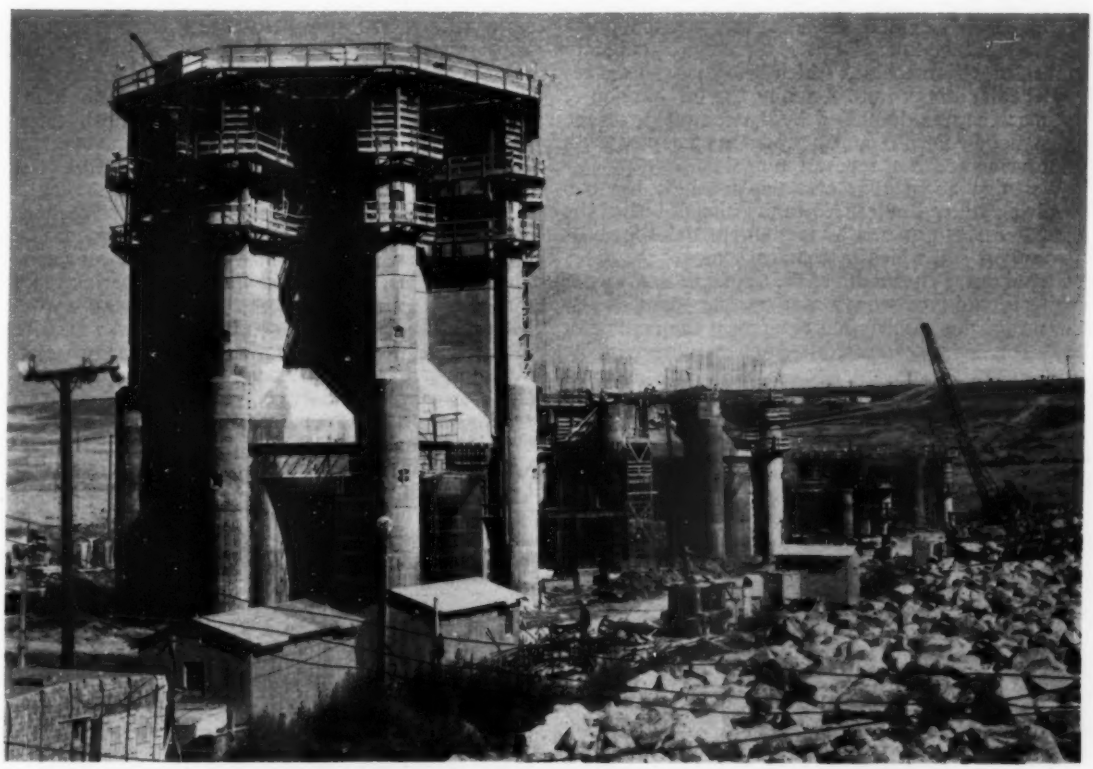

Fig. 9. Oahe power intake structure in course of erection

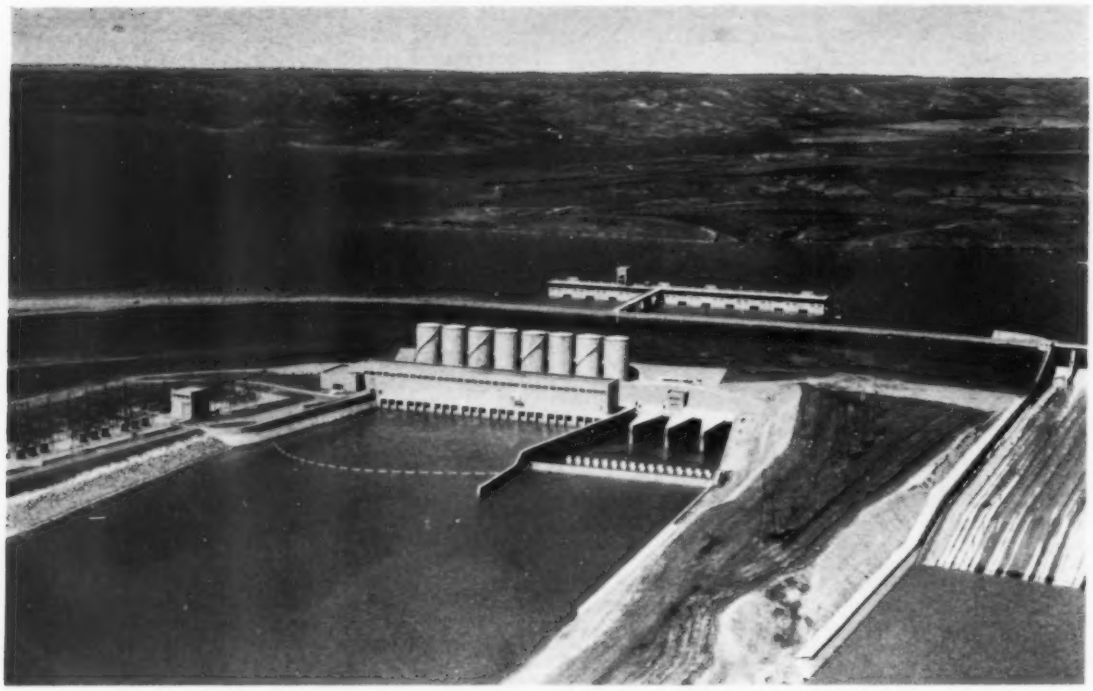

Fig. 10. Aerial photograph of Fort Randall dam and power plant

of about 140 ft below surface elevation. For this operation the contractors developed an ingenious mechanical boring machine, referred to on the job as a "Mechanical Mole." Fig. 7 is a picture of the early model of the machine, which has since been remodelled and improved. Actually, the first version of the machine was developed by the contractor on the Oahe flood-control tunnels, and then adapted with improvements for the power tunnels.

Weighing about 175 tons, this machine has two revolving cutter heads sized to the dimensions of the tunnel bore, is powered by large motors and includes a conveyor belt which mechanically moves the muck material out to the mouth of the tunnel. It is equipped with railroad-type wheels and operates on rails. By the use of this mechanised equipment the contractor has been able to bore 29-ft-diameter tunnels at an average rate of about 80 ft per day. This compares with about 12 to 24 ft per day by the old blast-and-muck method, as experienced at the Garrison project. Thus, tunnel mining on the Oahe job has been greatly expedited, with reduced costs and hazards to men and equipment. The machine has revolutionised tunnel mining on projects of this kind in the United States.

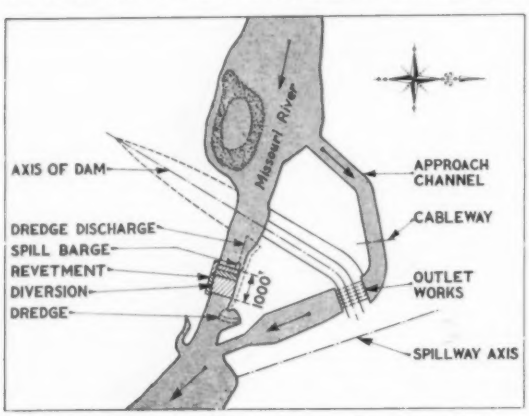

Fig. 11. Dredge-fill closure at Fort Randall

While the Pierre shale formation encountered at the Oahe project was particularly well adapted to this new mechanical mining process in general, the faults caused problems. In such faulted areas, roof sections of the bore frequently collapsed, showering tons of material on the machine and clogging its mechanism. This occasioned delays, but the overall performance was very satisfactory.

At the time of writing, construction of the massive intake structures for the power tunnels was progressing, as shown in Fig. 9. As previously mentioned, the Oahe power plant, when completed, will house seven generators with a combined installed capacity of 595 MW, making it the largest of the main-stem-system power plants. First power at Oahe is scheduled to go on the line in July 1962, and the last in the summer of 1964.

Big Bend Dam

In geographical sequence, the next of the authorised main-stem projects is the Big Bend dam and reservoir, 90 river miles below Oahe. The major determining factor in site location of Big Bend was to develop the favourable power head between Oahe and Fort Randall dams. Its primary function will be to supply electric power to the Basin area, although it will provide important public recreational benefits and perform some regulatory services.

The rolled-earth embankment will stretch 8,255 ft

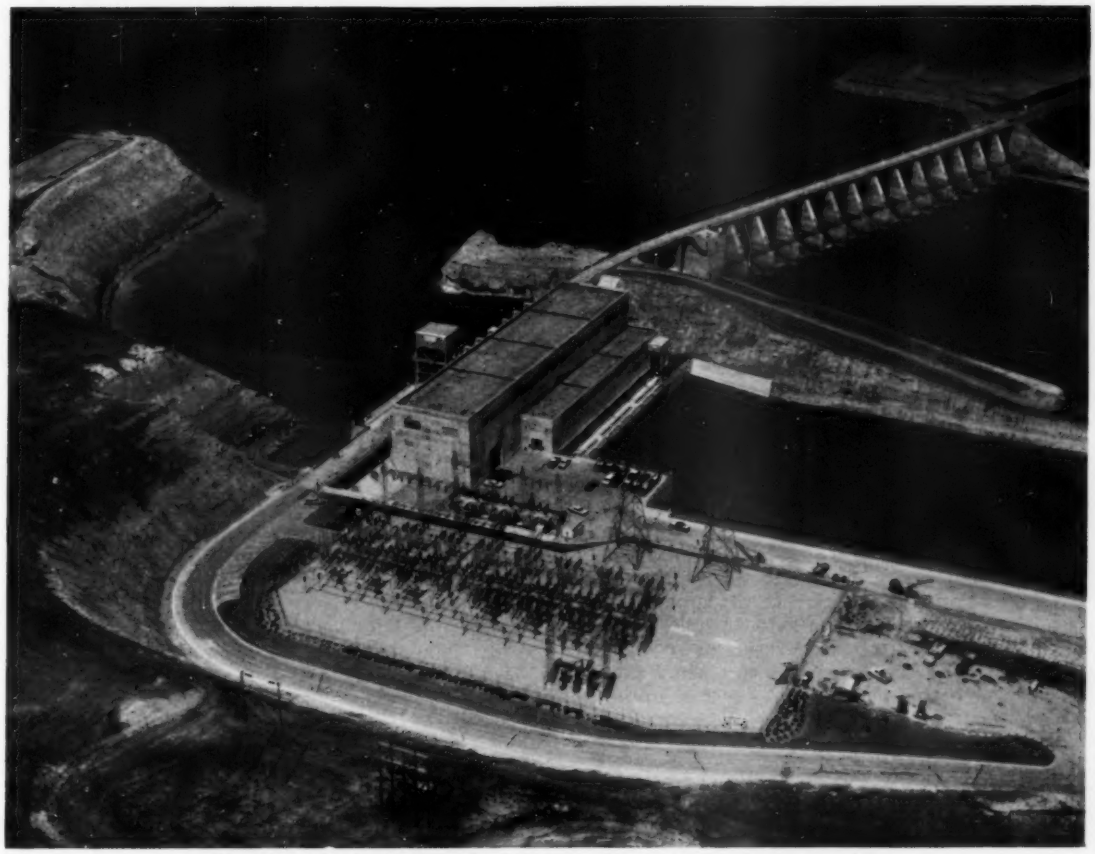

Fig. 12. Aerial photograph of Gavins Point dam and power plant

across the valley floor, rising to a crest height of 100 ft. Volume of earthfill is estimated at 17 million cu yards. The reservoir will extend about 80 miles upstream to Pierre. The power plant, second in size to Oahe, will house eight generators, each with a nameplate rating of 58·5 MW. The first is scheduled to go into operation in July 1964. Overall completion of the project is scheduled for June 1967.

The reservoir will have a maximum capacity of 1,900,000 acre ft, a length of 80 miles at maximum pool, and a maximum surface area of 55,800 acres.

Fort Randall Dam

The Fort Randall project took its name from an old frontier military post established by the US Army in 1856 for the protection of early settlers. Abandoned in 1892, the only visible remains of the Fort are the ruins of an Army Chapel. The site is in south-east South Dakota about 111 miles below Big Bend dam. Fig. 10 shows an aerial view of the completed dam and appurtenant works.

First of the major Missouri River main-stem dams to be constructed after Fort Peck, the Fort Randall dam construction pattern was similar to its other rolled-fill counterparts on the main stem. However, there were several distinctive features, particularly with respect to the method of closure of the river section of the embankment, and the material used to blanket the upstream face of the dam to prevent wave erosion.

While smaller in size than Fort Peck, Garrison, and Oahe, this projects ranks among the large rolled-fill dams of the world in its own right. The embankment is 10,700 ft long, 165 ft high, and required 50 million cu yards of fill material. The maximum reservoir capacity is 6·1 million acre ft, which at full pool will create a lake extending about 111 miles upstream to the Big Bend dam.

At this site the principal foundation material is called Niobrara chalk, a soft rock formation, but more stable than the Pierre shale upstream. This material lent itself to greater usefulness in the closure operation and as a material for facing the upstream slope of the dam.

In the summer of 1952, the Missouri River was diverted from its natural channel into the outlet-works tunnels previously constructed, by a unique method of choking off the main channel with a chalk fill placed by a huge dredge. When the dredged closure fill rose above the water surface, large earthmoving equipment dumped additional layers, raising the embankment to its full height, as seen in Fig. 11. This contrasted with the closure method employed at other main-stem dams, where this operation was accomplished by end-dump trucks placing material into the closure channel until it was closed off by dumping from a construction bridge at Fort Peck and Garrison, and by working out from both banks in the case of Oahe.

The chalk material available from excavations for

the intake, power-house and spillway structures, also was put to cost-saving advantage in facing the upstream portion of the embankment. The extensive upstream berm was constructed of compacted chalk, and a thick chalk blanket was placed on the upstream face of the dam to prevent wave erosion. This blanket, which was placed on a 1 in 15 bench slope, replaced the costlier method of riprap facing with stone which often had to be hauled from a considerable distance to the site.

The Fort Randall power house contains eight hydro generators of 40 MW each, for a total of 320 MW. It has been in essentially full operation since 1955. Another multiple-purpose project, Fort Randall functions for flood control, power production, improvement of downstream navigation and related public benefits, but does not presently include any provision for irrigation.

Gavins Point Dam

Lowermost of the main-stem system is the Gavins Point project, Fig. 12, near Yankton, South Dakota, the original territorial capital of Dakota Territory.

Gavins Point plays a somewhat specialised role in the integrated operation of the main-stem system, though much smaller in size than the larger units upstream. Its primary function is to reregulate fluctuating discharges caused by power peaking at Fort Randall dam so as to prevent objectionable fluctuation in stages along the Missouri downstream. It also has a sizeable power plant housing three generators for a total nameplate rating of 100 MW, and it provides some flood-control benefits.

Being the lowermost of the main-stem system, Gavins Point is the regulatory point for control of water releases for navigation during navigation seasons, and for low-flow winter regulation. During navigation seasons, which usually extend from late March to late November, the regulated releases from Gavins Point average about 28,000 cusecs. Winter-season flow requirements for water supply and sanitation, governed to some extent by winter icing conditions, average from 8,000 to 9,000 cusecs.

Commensurate with its purposes, Gavins Point dam is 74 ft high, 8,700 ft long, and creates a reservoir with a maximum capacity of 540,000 acre ft. The concrete spillway has a crest length of 1,180 ft, with a discharge capacity of 584,000 cusecs.

From a public-recreation standpoint, this project has proved highly attractive. The 1960 visitor-day count was over 1,400,000, major attractions being fishing, boating, water skiing, swimming, hunting, and picnicking. A visitor-day count of over four million was reported in 1960 at nine Corps reservoirs in the Missouri River Basin. Public relaxation and enjoyment thus have become important public benefits from these man-made lakes. Corps reservoirs throughout the United States attract over 100 million visitors annually.

Power Transmission

All of the main-stem Missouri River power plants are interconnected by a 230-kV and 115-kV transmission system, constructed and operated by the US Bureau of Reclamation which is the Federal marketing agency for Missouri River power. This system is part of the Interconnected Systems Group which has transmission ties with private and public power systems extending to the East Coast of the United States.

The Fort Peck power plant has interconnections to the West-Coast area via the Northwest Power Pool. The existing transmission ties leading west across the State of Montana are not presently adequate to hold frequencies of the two systems together, so the Fort Peck power plant supplies power to both systems through a sectionalised bus. Normally only one unit is connected to the Northwest system.

Reservoir Operations

While the Corps of Engineers is responsible by law for the operation and maintenance of reservoirs it builds, the regulation of an integrated system so large as that on the Missouri main stem involves many local and regional interests. Therefore, a special programme has been set up to provide broad State and Federal participation in the development each year of an Annual Operating Plan designed to provide equitable service to all authorised functions of the system.

This has been accomplished through a Reservoir Control Centre at the Corps' Division Office in Omaha, Nebraska, with the guidance of a special Co-ordinating Committee of State and Federal Agency representatives.

Each year an Annual Operating Plan for the main-stem reservoir system is prepared under guidance of the Co-ordinating Committee For Missouri River Main-Stem Reservoir Operation. The Committee is composed of representatives of the ten Missouri Basin States and eight Federal Agencies. This Committee co-ordinates the viewpoints of all interests concerned with the main-stem system operations.

The Annual Operating Plan approved by this Committee governs the operations of the reservoirs through the ensuing year. The Reservoir Control Centre is staffed with a group of hydraulic experts, meteorologists, and other specialists, especially equipped to meet the requirements of Missouri-River reservoir operations. It maintains direct working contact with related activities at the projects, the Corps of Engineers District Offices, the Bureau of Reclamation's Regional and Power Systems Operating offices, the Weather Bureau, and other agencies.

Overall Co-ordination

The Missouri Basin Inter-Agency Committee was established early in 1945 and has functioned continuously as the major co-ordinating agency in connection with the overall Basin water-resources programme. This Committee functions to safeguard the rights and interests of all concerned and to facilitate co-operation among the various Federal Agencies and the States involved. It is composed of one representative each of the eight interested Federal Agencies, and the Governors of the ten Basin States. It meets bimonthly at various locations throughout the Basin. The meetings are open to the public.

Run on a democratic and voluntary basis, this Inter-Agency organisation has succeeded in solving many of the problems that necessarily arise in the process of such a large undertaking in a major region of the United States. By reason of the flexibility afforded through the democratic processes and co-operation of the various agencies, the needs of the entire Basin can be anticipated and appropriate methods devised for their fulfilment.

Utilising the Qattara Depression

The author proposes a new method of utilising the difference in level between the Mediterranean Sea and the Qattara Depression, in the Western Desert of Egypt, for the generation of electric power

By M. KAMAL GOHAR*, M.Sc., Ph.D.

FIG. 1 is a general map of the Qattara Depression showing the principal contours, from which it can be seen that the lowest point in it is about 134 m below sea level. It has been suggested that a conduit between the sea and the Depression could be constructed so that sea water could be permitted to pass continuously into the Depression, thus forming a large lake. The depth and surface area of this lake would be increased gradually until a certain level would be reached at which the total quantity of water reaching the Depression in a given time would be equal to the effective total quantity of water escaping from it by evaporation and outward seepage.

Dr. J. Ball† suggested the line *A* in Fig. 1 as an appropriate route for the conduit. A cross section of this route is shown in Fig. 2, which also gives the known geology along the route. By knowing the maximum and the average available quantity of water passing into the Depression and the corresponding effective head, Dr. Ball calculated the maximum and

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† J. BALL, O.B.E., D.Sc., Ph.D., A.R.S.M., M.I.C.E., F.G.S., F.R.G.S. "The Qattara Depression of the Libyan Desert and the Possibility of its Utilisation for Power Production," *The Geographical Journal*, October 1933, The Royal Geographical Society, London

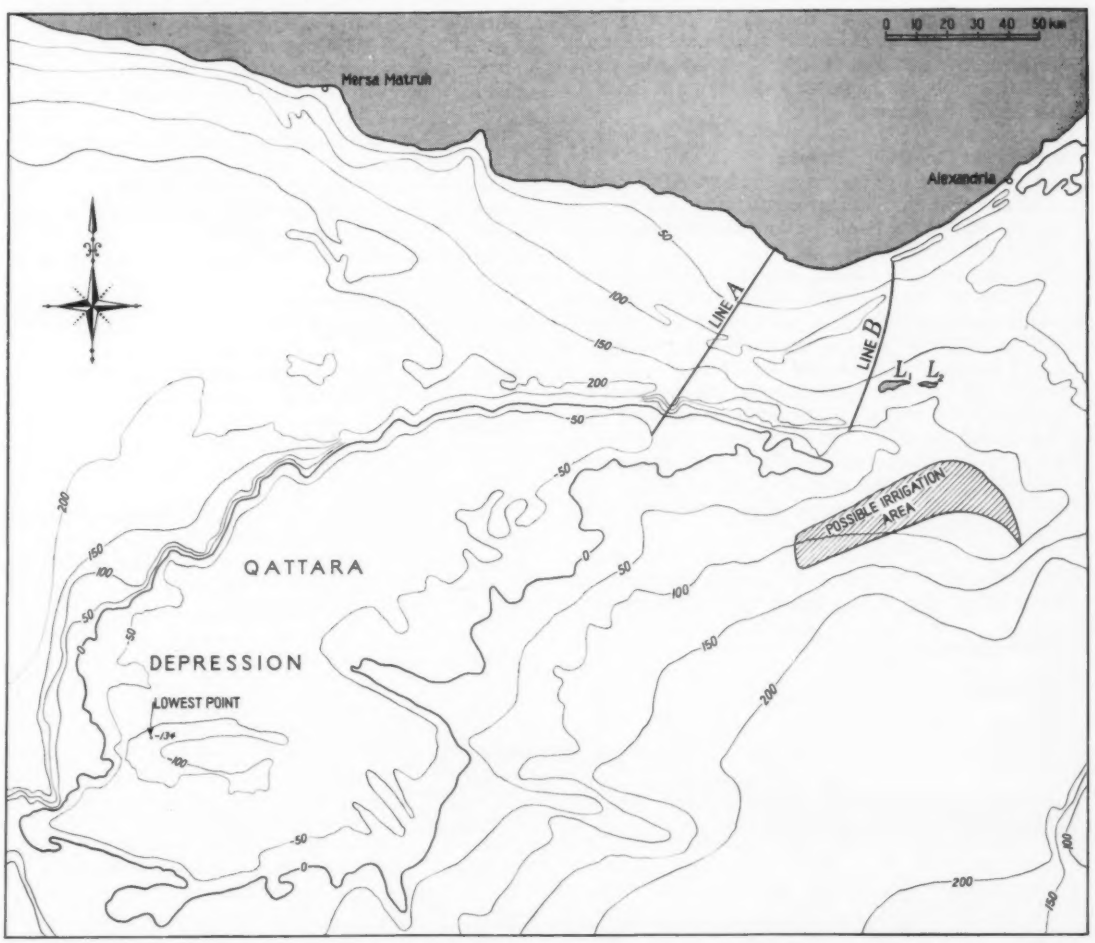

Fig. 1. Map of the Qattara Depression, showing Dr. Ball's and the author's proposed conduit routes and the lakes mentioned by the author

TABLE I.—DETAILS OF DR. BALL'S PROPOSALS

Final lake surface level, m	−50		−60		−70	
Surface area, km²	13,500		12,100		8,600	
Diameter of tunnels, m	12	11	11	9·5	9·2	8·2
Corresponding power from three tunnels, MW	200	175	200	150	150	125
Total cost, £million,	210·19	182·966	217·32	169·97	174·41	144·1
Cost/kW, £/kW	1,050	1,030	1,087	1,125	1,160	1,150

the average power that could be obtained from the depression at the surface water levels of − 50, − 60, and − 70 m. A summary of these results is given in Table I, together with estimated costs and the corresponding cost per kW calculated by the present author. The capital costs were estimated by comparison with the costs of similar projects in Egypt, e.g., Aswan hydro-electric scheme, Mex pumping station, etc.

A lake having a final level of − 50 m would take more than 120 years to fill and could develop more than 200 MW, but Dr. Ball considered an output of about 175 MW, with a lake at this final level, to be the best from the financial point of view.

At that time (1930) it was suggested that the power from the Qattara should be transmitted to the Delta area. However, the situation is different now as there are many thermal power stations in the area. The hydro-electric power should be mainly utilised in the Qattara area itself, the residual output being transmitted to supply the Delta area during peak loads, or as an auxiliary system.

Remarks on Dr. Ball's Scheme

(a) The line *A* in Fig. 1 was chosen by Dr. Ball on the assumption that it represented the shortest distance between the sea and the contour level of − 50 m in the Depression.

(b) From Fig. 2 it can be seen that the ground surface along the line *A* rises gradually from the sea towards the Depression to a point about 240 m above sea level. All the possible methods for making the conduit between the sea and the Depression in the direction of *A* lead to relatively high costs. The cheapest of Dr. Ball's suggestions was to drive three tunnels, each about 10 m in diameter and 60 km long; the rest of the conduit would be an open channel. The total cost of this scheme was estimated to be more than £100 million, which would considerably affect the economics of the project.

(c) If the same type of equipment is to be used as that previously employed in driving the tunnels of the Aswan hydro-electric scheme, it will take a long time to drive tunnels for the Qattara scheme, and also to line them with concrete of good workmanship. That is why Dr. Ball pointed out many times in his report the difficulties that would be met with such a scheme. At the end of his report he asked for some possible alternative schemes, based on the tabular summary of some of the main conclusions reached from his experimental and theoretical study.

(d) Surge tanks or impounding reservoirs would be essential for the long-tunnel scheme, thus increasing the total cost.

(e) The quality of the rock through which the tunnels would pass is unreliable, and might prove to be troublesome.

An Alternative Scheme

An alternative route, *B*, Fig. 1, is suggested, and a longitudinal profile along it is shown in Fig. 3. This appears to be a good basis for a more advantageous scheme, which will be discussed in the following paragraphs.

The highest point along the route is only about 11 km from the sea. According to Fig. 3, sea water could be pumped to a convenient point, *a*, for example, and then the water could be passed in an open channel, *ab*, which could be made much more easily and cheaply than the three tunnels previously mentioned.

If P_1 is the electric power in kW needed for pumping, it can be deduced that:

$$P_1 = 11{\cdot}8QH_1 \qquad \ldots (1)$$

where Q = quantity of water passing in m³/sec
H_1 = water head from point *a* to point *c*, in metres, and 11·8 is the constant of conversion taking into consideration the density of sea water, transmission and pump efficiency, etc.

When the water reached point *b* it would be directed towards the underground power station at *c* or c_1 or c_2 according to the lake level required. If the head from $b = H_2$ m, then similarly to equation (1), the power generated must be $P_2 = 8{\cdot}9QH_2$ ... (2)

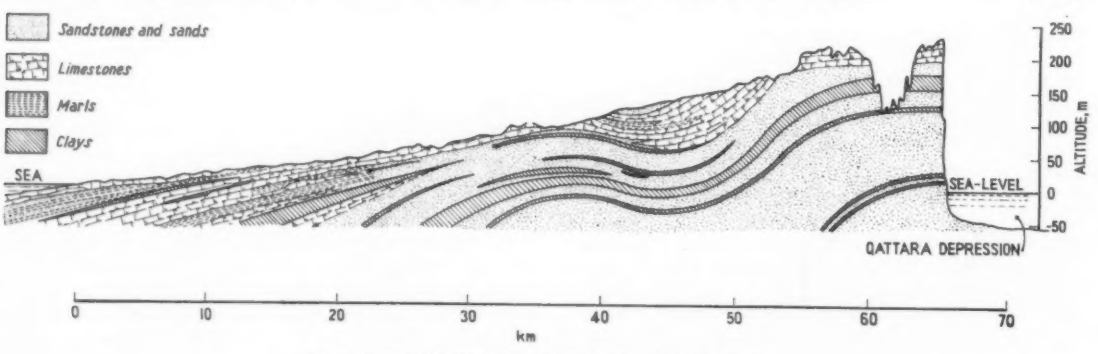

Fig. 2. Geological profile of Dr. Ball's route

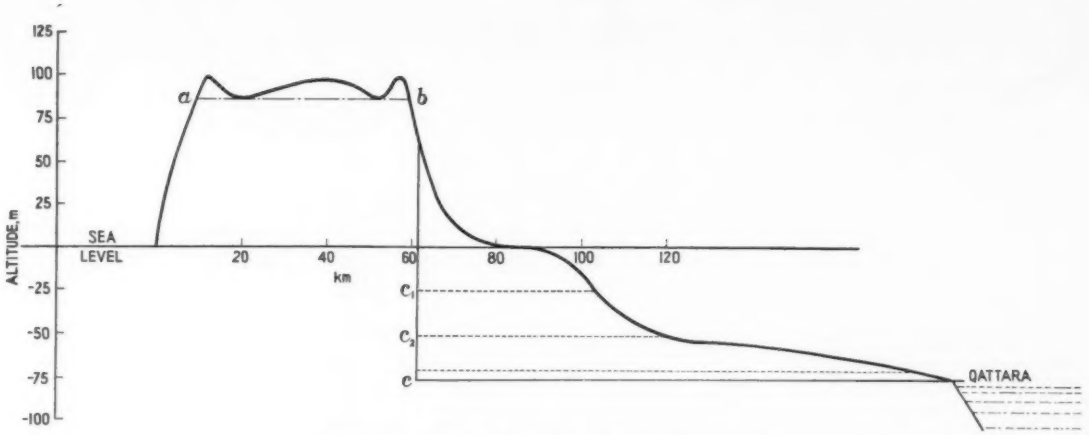

Fig. 3. Profile of the author's proposed route

If the power loss in this method is P_3, then a range between two values of electric power will be available. The first one is the continuous net power $P_n = P_2 - P_1 - P_3$ ... (3) which will be obtained after transmitting the required electric power to the pumps at the beginning of the conduit from the power station at *c*, for example. This power can be used continuously, i.e., 24 hours per day.

The second one is $P = P_2 - P_3$ ... (4) which can be used for some intervals in the day only (7–9 hours) when the pumps are shut off during this period. The water will be taken from the channel *ab* in this case during the peak-load hours and returned to it again by pumping during the off-peak hours. The time for utilising all the power P in equation (4) can be increased to about one month continuously if the artificial lakes L_1 and L_2*, which are near to the conduit *ab*, as shown in Fig. 1, are used as pumped-storage reservoirs.

This new scheme gives a storage plant without extra cost. Table II gives different values for P and P_n corresponding to the following conditions: lake-surface level – 75 m, water velocity 0·8 m/sec, rate of discharge 266 m³/sec, channel level 80 m, continuous net power $P_n = 100{\cdot}2$ MW, maximum available power when the pumps are shut off $P = 345$ MW.

By this method the cost/kW installed can be referred to either one of the two powers P or P_n as shown in Table II. In both cases the cost/kW as estimated by the author is less than the corresponding value given in Table I.

This scheme does not need a special surge tank or impounding reservoir, as the open channel *ab* or the artificial lakes L_1 and L_2 can be used instead, whereas it was essential in the tunnel scheme.

The level of the channel *ab* may be decreased so as to decrease the electric power required for the pumps at the beginning of the conduit; on the other hand the excavation cost will be greater. The costs/kW for different channel levels and different water velocities were considered and are shown in Fig. 4, from which the suitable cases can be chosen.

In addition to the pumped-storage plant previously mentioned, there is another type of pumped-storage system that could be used with advantage to increase the useful energy capacity of either the existing thermal power stations or the hydro-electric power station at the Qattara Depression. This will decrease the average cost/kW for both these thermal and hydro-electric stations to a considerable extent. The method can be explained as follows:

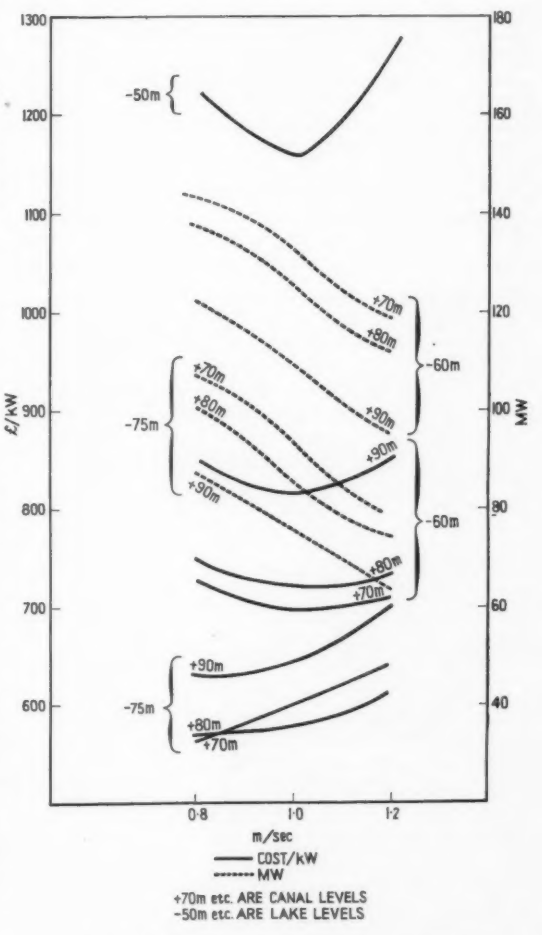

Fig. 4. Capacity and cost/kW curves

* These small depressions were not indicated in Dr. Ball's work, but they were located with the assistance of the Survey Department of Egypt.

TABLE II.—DETAILS OF THE REVISED POWER SCHEME

Final Lake level	Rate of discharge	Water velocity	Average channel level	P_n	P	Cost /kW for P_n	Cost /kW for P
m	m³/sec	m/sec	m	MW	MW	£	£
		0·8		88	373	630	152
		1·0	+90	75	364	646	139
		1·2		64	345	705	131
−75	266	0·8		100	345	568	166
		1·0	+80	85	336	605	152
		1·2		72	323	645	143
		0·8		122	690	850	150
		1·0	+90	111·5	675	819	126
		1·2		95·5	659	850	124
−80	542	0·8		138	649	750	160
		1·0	+80	126	632	725	145
		1·2		112	625	740	132

Fig. 5 represents the load curves of a thermal power station in different months of the year. By using the off-peak thermal power to supply the pumps at the Mediterranean shore, additional useful power would be stored for use during peak-load periods. According to the actual power and load curves of the steam stations in Egypt the expected additional electric energy and power would be about $1{\cdot}4 \times 10^6$ GWh and 150 MW respectively, which should be added to the other corresponding values given in Table II.

From this point of view the corresponding cost/kW generated = 2·7 milliemmes approximately against about 4·8 milliemmes for the existing thermal stations in Egypt; thus a saving of more than about £2 million every year could be achieved by using such a method.

A further possibility arises because in Egypt there are certain hydro-electric schemes, such as Aswan, in which the water flow depends mainly on irrigation requirements and not on the power demand. Surplus electrical energy is thus available which could be stored in the Qattara plant. The available energy, in fact, might be greater than the capacity of the Mediterranean storage pumps, in which case further pumps might be installed in the Depression itself to return water thence to Lakes L_1 and L_2. This would retard the filling of the Depression and prolong the life of the scheme.

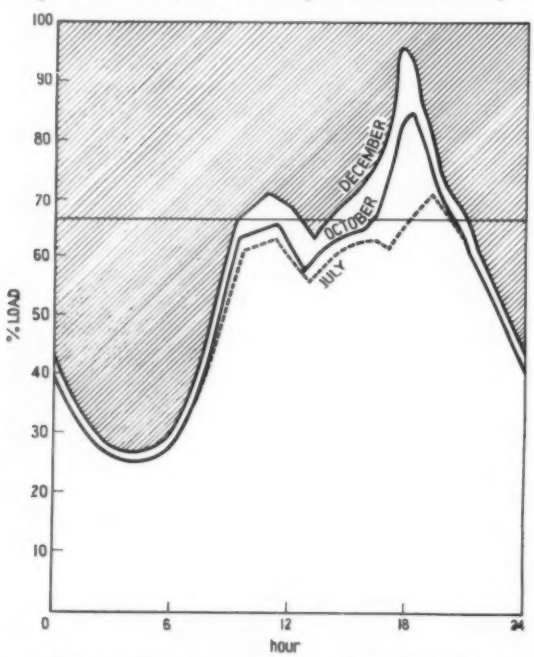

Fig. 5. Load curves for a thermal station

About 70% of the total power generated from the Qattara Depression could be utilised in the Qattara area itself, e.g., for pumping underground water or otherwise irrigating the large land area available for agriculture there. More than 5,000 km² of the Qattara area near the proposed power stations has a groundwater level less than 80 m from the surface. If this or some other industrial utilisation could be devised, a considerable decrease in the cost of electric energy would result and the cost could drop to less than one milliemme/kWh.

It would be easier to maintain the water conduits than it would be in the case of the tunnels. Moreover, the open-channel method in this region is safer than the other one.

The positions of the conduit, power station and area of utilisation as suggested here are about 50 km from the Alexandria area, a much shorter distance than conduit *A* suggested by Dr. Ball. This is an important advantage, and communications between the chosen part of the Depression and the nearest civilised part in the country would be as short as possible.

Finally, this scheme could be carried out in two stages according to the increase in the electric-power demand and financial considerations.

Civil-Engineering Films and Models. The Federation of Civil Engineering Contractors has prepared an up-to-date list of films and models available from its members. The list includes no less than 111 films and 14 models of many of the varied activities of the civil-engineering contracting industry, including harbours, roads, bridges, airports, hydro-electric and other power projects, oil refineries, water-supply schemes, sewerage schemes and industrial projects. The films and models may be borrowed, usually without charge, from the members concerned. The list itself is obtainable post free from the Federation of Civil Engineering Contractors, Romney House, Tufton Street, Westminster, London, S.W.1.

Rotating Guide Apparatus for Axial Pumps and Turbines

In order to offset the whirl component in the velocity of the water leaving a runner, the author proposes the use of a rotating guide apparatus. The author's proposed self-adjusting double-runner system is also discussed

By Dr. Ing. CAHIT ÖZGÜR*

IF axial-flow pumps have no guide vanes before or after the runner, there may be a very large whirl component in the velocity of the water leaving the runner. As it is not easy to recover the rotational component of velocity, the losses are excessive and efficiency is low. Furthermore, strong swirling flow after the runner often causes instability and power oscillation.

When the pump is equipped with a set of fixed guide vanes, the whirl component may be removed from the water, but only for one, optimum, flow condition. For discharges and heads other than the design values, not only does the whirl reappear but there may also be separation of flow from the guide vanes, which is an additional source of loss. Similar reasoning may be applied to propeller-type turbines, in which head or load variations give rise to similar difficulties.

It is proposed in this article that a rotating guide apparatus (in effect a second runner) should be set at the outlet, and its possible effect is examined. A new self-adjusting double-runner system (the subject of a patent application) is also discussed.

Constant-Speed Runners

Let A be the upstream runner and B the downstream runner of a pair rotating in opposite directions (Fig. 1). Consider a representative cylindrical section, of radius R, for which the velocity diagram represents the average condition of flow through the runners.

The following are the notations:

Runner A	*Runner B*	
W_1, W_2	W_1', W_2'	= relative velocities (inlet, outlet)
V_1, V_2	V_1', V_2'	= absolute velocities (inlet, outlet)
U	U'	= runner velocity
V_a	V_a'	= axial velocity component
V_{u1}, V_{u2}	V_{u1}', V_{u2}'	= tangential velocity component
$\Delta V_u = V_{u2} - V_{u1}$	$\Delta V_u' = V_{u2}' - V_{u1}'$	= whirl imparted by the wheel (deflection)
$\vec{W}_\infty = \frac{\vec{W}_1 + \vec{W}_2}{2}$	$\vec{W}_\infty' = \frac{\vec{W}_1' + \vec{W}_2'}{2}$	= average velocity
θ	θ'	= blade angle (angle between zero incidence direction and the runner velocity vector)
α	α'	= real angle of incidence
β	β'	= angle between $\vec{W}_\infty$ and $\vec{U}$

For axial inlet flow (without whirl) when the machine is working as a pump, the velocity diagrams of the two runners are shown in Fig. 2. Water approaching the runner A with a relative velocity $\vec{W}_1$ will be deflected by the blades in the direction of runner A's rotation and will leave this runner with relative velocity $\vec{W}_2$, resulting in a whirl component $\Delta V_u = V_{u2}$.

It is easy to see from the velocity diagram that when $U = U'$ and $\theta = \theta'$, the angles of incidence and of relative velocity for the second runner have higher values; consequently deflection $\Delta V_u'$ will be greater than ΔV_u. That is to say, there will always be a whirl component at the outlet of the second runner, in the direction of the runner's rotation. Nevertheless, the whirl can be reduced in this way, the reduction depending on the numerical values of angles and velocities.

With a constant-speed runner, straight outlet flow can be achieved in two ways:

(a) DIFFERENT-PITCH RUNNERS

It is possible, for a given discharge, blade angle θ and speed U, to obtain straight flow at the outlet of the second runner by properly choosing the angle θ'. In order to calculate this angle θ', a simplified aerofoil theory will be used. By this means we will have a general picture of the flow through two contra-rotating runners.

Calculation of Blade Angle. Application of the momentum theorem to flow through a cascade leads to the following expression[1]:

$$C_L \frac{c}{d} = 2 \frac{\Delta W_u}{W} + \frac{\Sigma \xi}{1/2\ W^2 \tan \beta} \qquad \ldots (1)$$

where $\frac{c}{d} = S$ is the solidity, C_L lift coefficient, $\Sigma \xi$ total losses.

Experience has shown that friction has little effect on the velocity deflection, so that for the first approximation the fluid can be regarded as non-viscous. The above equation then becomes:

$$\frac{2\ \Delta V_u}{W_\infty} = C_L\ S \qquad \ldots (2)$$

For a given profile, C_L is generally a function of the angle of incidence α. For aerofoil profiles, experimen-

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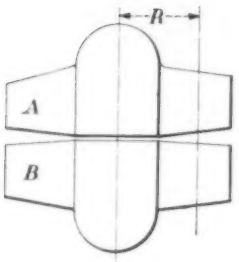
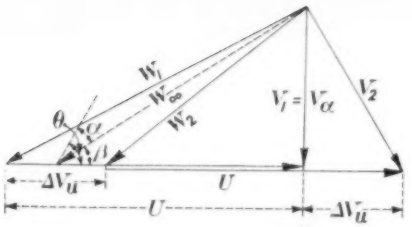




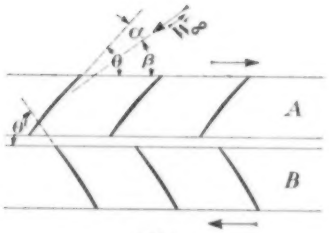


FIG. 1

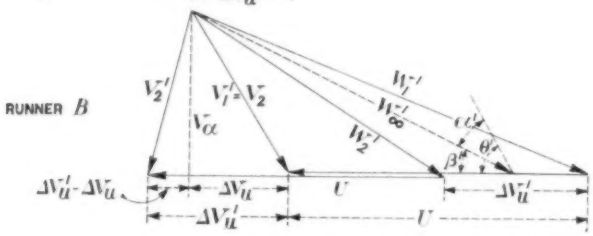


FIG. 2

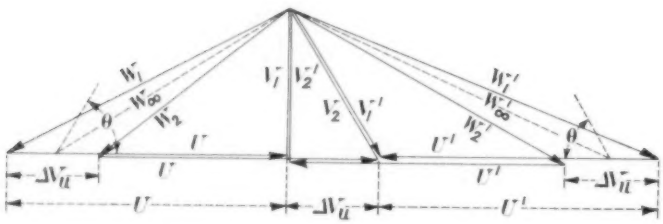


FIG. 3

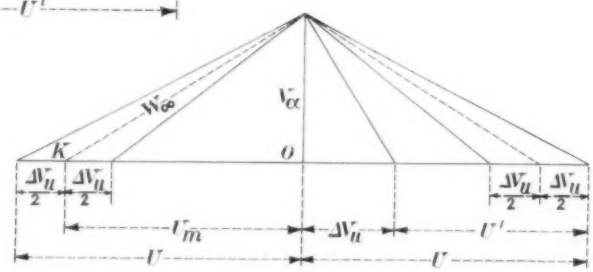


FIG. 4

tal polar curves are given in data books[2]. When there is no stall on the blade, the following empirical formula gives fairly good results on a large amount of profile:

$$C_L = 0{\cdot}1\ \alpha \qquad \ldots (3)$$

where α is in degrees. On the other hand, according to thin aerofoil theory, the correct expression of C_L with potential flow around an isolated profile is[2]:

$$C_L = 2\ \pi\ \sin\ \alpha = 2\ \pi\ \sin\ (\theta - \beta) \qquad \ldots (4)$$

Using this expression, from (2) we obtain:

$$\frac{\Delta V_u}{V_a} = \frac{\sin\ (\theta - \beta)}{\sin\ \beta}\ S\ \pi \qquad \ldots (5)$$

and from the velocity diagram, we have:

$$U - \frac{\Delta V_u}{2} = V_a\ \cot\ \beta \qquad \ldots (6)$$

In the two final relationships the only unknowns are β and ΔV_u. These can be calculated and, therefore, the velocity diagram can be determined for runner A.

Similarly, the following relationships apply to runner B:

$$\frac{\Delta V_u'}{V_a} = \frac{\sin\ (\theta' - \beta)}{\sin\ \beta} \qquad \ldots (7)$$

$$U + \frac{\Delta V_u'}{2} = V_a\ \cot\ \beta' \qquad \ldots (8)$$

Here, replacing $\Delta V_u'$ by the value ΔV_u, calculated as previously shown, the blade angle θ' required for straight outlet flow can be found. The combined velocity diagram corresponding to whirl-free outlet flow is shown in Fig. 3.

For a more accurate calculation, the cascade effect on the lift coefficient must be taken into account.

(b) Different-Speed Runners

Instead of choosing a different blade angle for runner B we could fix its speed to obtain axial-flow outlet. This time U' must be smaller than U. The preceding formulae are still valid in their original forms and, in addition, some simplifications may be made. So, for straight outlet and two equal-pitch runners,

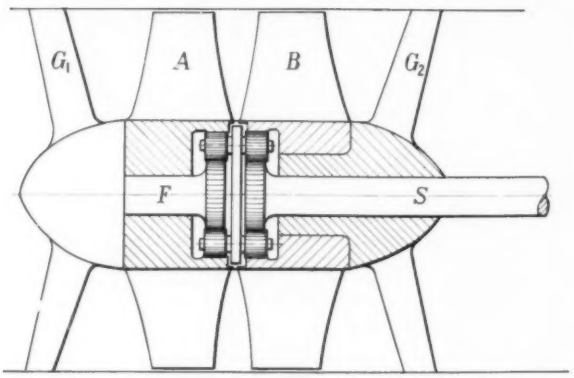


FIG. 5

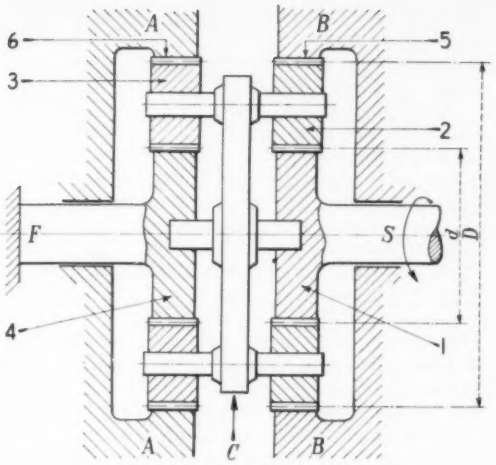


FIG. 6

the main formulae to be used are equation (2) and

$$U = U' + \Delta V_u \qquad \ldots (9)$$

Where $\alpha = \alpha'$ $\theta = \theta'$ $W_\infty = W_\infty'$

In both cases, (a) and (b), straight axial flow can be maintained for only one discharge. When the flow differs from that for which the speed or angle of runner *B* has been calculated, the deflections of velocity in the two runners are no longer the same and they do not cancel out.

The greater the deviation from the optimum conditions, the larger is the final whirl component in the discharge pipe. However, in partial discharge, rotating guide vanes give better results compared with the fixed ones because of the fact that the combined velocity diagram is nearly symmetrical for case (a) and completely symmetrical for case (b) in respect of relative velocities (see Fig. 3). Therefore, a slight departure from the optimum conditions will cause a similar effect on the flow through both runners and the deflections will be compensated to some extent.

Variable-Speed Runners

Suppose runners *A* and *B* have identical blade profiles and are set inversely. We have seen that, for the second runner to accommodate the whirl component imparted to the water by the first runner, the second runner should be given a determined speed, depending on the deflection corresponding to the given discharge.

The relation to be satisfied is simply

$$U' = U - \Delta V_u \qquad \ldots (9)$$

Two cases are to be considered:

(a) RUNNER *A* DRIVEN WITH CONSTANT SPEED AND RUNNER *B* DRIVEN WITH VARIABLE SPEED

This needs a speed adjustment according to the flow, i.e. a variable-speed motor and a governor, which means additional cost. Despite this disadvantage, this system would have the advantage that, by adjusting the speed of one runner, the discharge could be varied for a given head.

(b) TWO RUNNERS HAVING DIFFERENT AND VARIABLE SPEEDS

Suppose two runners are given a proper speed combination to satisfy the straight outlet conditions (i.e., equation (9)) for all discharges. The combined velocity diagram that corresponds to all flow conditions will, in that case, be as shown in Fig. 4.

Again, applying Euler's theorem, the torque can be found for each runner.

$$M = \rho\ Q\ R\ \Delta V_u$$

$$M' = \rho\ Q'\ R'\ \Delta V_u'$$

Since Q, R and ΔV_u are the same for both runners, the torques must necessarily be the same, i.e., $M = M'$.

If, therefore, we devise a driving system satisfying the above equations for all conditions, the deflection for the two runners will have the same magnitude but opposite direction; in other words, equation (9) will automatically be fulfilled and the outlet flow will be whirl-free for any discharge.

Equal-Torque Driving Systems

A properly chosen planetary gear system is one of the solutions for driving two contra-rotating runners with equal and opposite torques. Fig. 5 shows such an arrangement capable of transmitting equal torque to both runners and practicable from the standpoint of design. Runners *A* and *B* are driven by a constant-speed shaft *S* through planetary gears. G_1 and G_2 are the supporting ribs which carry the bearings of the runners. It can easily be seen that the pump operates in the same manner when the flow is reversed, providing that the shaft *S* is driven in the reverse direction. This arrangement could, in addition, function as a turbine in either direction, driving the shaft *S*, which would be connected to the generator.

Description of the planetary system is as follows (Fig. 6):

Gear *1* is directly fastened to the main shaft *S* and rotates at the same speed *n*. Gear *4* is fastened to the stationary shaft carried by supporting ribs G_1 (Fig. 5). Disc or spider *C* carrying the planet gears *2* and *3* rotates idly about the main axis with a speed n_c. Its short central shaft is guided and supported by *F* and *S*. On the periphery of disc *C* are mounted several small shafts on which planet gears *2* and *3* rotate idly. Internal gears *5* and *6* are of equal diameter and are fixed inside the runner hubs. The speeds of these gears are n_A and n_B (positive direction for runner *B*, being opposite to that of the main shaft).

Analysis of the above system leads to the following speed relation:

$$\text{Speed of main shaft, } n_s = (n_A + n_B)\,\frac{D}{d} \qquad \ldots (10)$$

where D is the diameter of gears 5 and 6, and d that of the gears 1 and 4. Note that when $D=2d$, the speed of the driving shaft S is four times greater than the mean speed of runners A and B.

Again, it can also be shown from the analysis that when the system is in dynamic equilibrium, torques applied to runner A and runner B are always equal. Thus, when the shaft of a pump like the one shown in Fig. 5 is driven with a constant speed, n_s, each of the two runners will choose its own speed until the torques are equal, and straight outlet flow results. As the discharge changes, the runners will have another right combination of speed to suit the new condition, always giving whirl-free outlet.

It should be noted that, according to equation (10), the mean value of the two runner speeds is constant for all equilibrium conditions. In the case of $D=2d$, the shaft speed is four times higher than the mean runner speed. This, of course, gives an additional advantage which enables us to increase the generator or motor speed considerably, without causing cavitation trouble in the runner. Another possibility is an electrical drive consisting of a rotating armature on one runner and a rotating field on the other. The relative speed in that case will always be constant, and the electrical torques applied to the runners will necessarily be equal.

Head-Discharge Characteristic of the Proposed System

The theoretical head of the proposed pump for a given discharge can easily be evaluated.

The following relations were shown or implied:

$$U=U'+\Delta V_u \qquad \ldots (9)$$

and

$$\left(\frac{n_A+n_B}{2}\right)=\frac{d}{2D}\,n_s=\text{constant (from equation (10))} \qquad \ldots (11)$$

From equation (11)

$$\frac{U+U'}{2}=\frac{d}{D}\,n_s\,\frac{2\,\pi\,R}{60}=U_m \qquad \ldots (12)$$

From equations (9) and (11) we get

$$U=U_m+\frac{\Delta V_u}{2} \qquad \ldots (13)$$

U_m is constant for constant-speed drive, and the speed of runner A varies linearly with the deflection ΔV_u, e.g., for zero deflection the two runner speeds will be equal.

This relationship indicates also that point K on Fig. 4 is fixed whatever the flow conditions. This fact makes the diagram and calculations quite simple.

From equation (5) the deflection may be written:

$$\Delta V=W_\infty\,\pi\,S\,\sin\,(\theta-\beta)$$

and since point K is fixed, the velocity diagram gives:

$$W_\infty=\frac{U_m}{\cos\,\beta}$$

Then

$$\Delta V_u=U_m\,2\,\pi\,S\,\frac{\sin\,(\theta-\beta)}{\cos\,\beta} \qquad \ldots (14)$$

On the other hand, the axial velocity is simply:

$$V_a=U_m\,\tan\,\beta \qquad \ldots (15)$$

Manometric heads are given by the Euler formula.

For pumps (assuming no friction) we have:

$$H=\Delta V_u\,U\,\frac{1}{g}$$

$$H'=\Delta V_u\,U'\,\frac{1}{g}$$

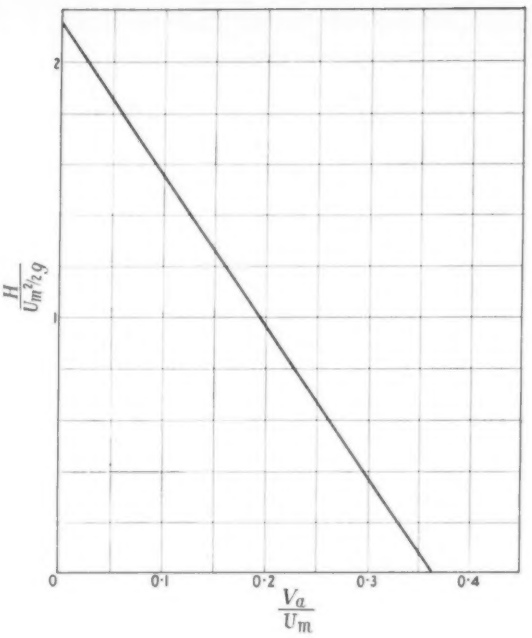


FIG. 7

The total head becomes:

$$H_T=\frac{\Delta V_u}{g}\,(U+U')=\frac{\Delta V_u}{g}\,U_m \qquad \ldots (16)$$

From equations (14), (15), and (16) we obtain, in dimensionless and parametric form, the relationships between head and discharge, the latter being expressed in terms of axial velocity.

$$\frac{2\,g\,H}{U_m^2}=4\,\pi\,S\,\frac{\sin\,(\theta-\beta)}{\cos\,\beta} \qquad \ldots (17)$$

$$\frac{V_a}{U_m}=\tan\,\beta \qquad \ldots (18)$$

As an example, the theoretical head-capacity curve has been plotted in Fig. 7 for a double-runner pump, with a blade angle of 20° and solidity S of 0·5.

Advantages of the Proposed System

In spite of some mechanical difficulties to be overcome, such as that of sealing the gearbox, this system is expected to offer the following advantages over the conventional axial pump and turbine:—

1. Because whirl-free outlet flow is obtained whatever may be the rate of discharge, the discharge losses will be reduced and overall efficiency will be improved for a very large range of operation. Recent investigations on draft tubes have shown that the high whirl component not only cannot be recovered, but impedes the recovery of the axial component[4].
2. The cavitation condition is improved for two reasons:
   (a) The head is split over two runners.
   (b) For turbine operation, the radial pressure gradient is eliminated at the outlet.
3. Voids and surges caused by swirling flow in the discharge tube are eliminated; smoother and more stable running is to be expected.
4. For pumps with relatively long discharge pipes, the high friction losses formerly caused by swirling flow in the pipes will be diminished.
5. Though there is, on the average, no whirl component at the outlet of the machine, there may be some rotation changing direction between hub and tip. However, a small tangential velocity may only im-

prove the draft-tube efficiency by helping to avoid separation[5]. Furthermore, if for any reason it is desired to give the water a slight whirl component, the planetary gear system can be chosen to supply different torques by giving the gears different diameters.

6. The arrangement is suitable for axial turbines, pumps and pump-turbines, and for either forward or reverse operation.
7. The driving system is simpler than that of the individually driven contra-rotating arrangement which has been reported recently in Russia.
8. The peak efficiency of the proposed unit is expected to be higher than that of conventional pumps with outlet straightening vanes, because, in the latter case, the whirl component is recovered in the vanes at the expense of some extra losses, whereas in the new arrangement there is no need to recover any component at the outlet of the unit.

REFERENCES

1. SCHLICHTING, H., "Application of Boundary-Layer Theory in Turbomachinery," *A.S.M.E. Transactions*, Series D, December 1959.
2. WISLICENUS, F., "Fluid Mechanics of Turbomachinery," pp. 218-224, McGraw Hill Inc., 1947.
3. Özgür, C., "Étude Experimentale de l'Écoulement Helicoidal dans les Tuyaux Droits." Thesis submitted to the Technical University of Istanbul, 1953.
4. Özgür, C., "Contribution à l'Écoulement Giratoire dans les Divergents." Thesis submitted to the University of Paris, 1960.
5. PETERS, H., "Energieumsetzung in Querschittserweiterungen bei Verschiedenen Zulaufbedingungen," Ingenieur Archiv II Band Erstes Heft, March 1931.

The Vianden Pumped-Storage Project, Luxembourg

In our March 1960 issue we published an account of the Vianden scheme in Luxembourg, with the details as they were then known. A more up-to-date description is given in a booklet, which is printed in English, entitled "The Vianden Pumped Storage Plant." This is by Karl Böhler, and is a special print of two articles from *Energiewirtschaftliche Tagesfragen*, the first of which recorded progress up to mid-1960, and the second to the end of 1961. Interested readers can obtain a copy of the booklet from the editorial offices of WATER POWER within the limits of the stock at our disposal.

The main difference to be noted since the original description was prepared is that the capacity and efficiency of the sets have been increased. The development is to be carried out in two stages, each of which was intended to include four 100-MW generating units. This is itself a considerable advance on the original scheme; however, the latest information is that the second stage is to be enlarged to accommodate a fifth set. Thus the ultimate generating capacity will now be 900 MW.

A significant feature of the Vianden development is that the overall efficiency will now be about 75%, according to the plant manufacturers' guarantees. Under optimum conditions, 77% efficiency is anticipated.

Progress on the work, which began in 1959, has been good, and it is expected that the first sets will come into operation in the autumn of 1962. Much of the first-stage civil-engineering work is already well advanced.

Code of Practice for the Maintenance of Electric-Motor Control Gear

A new code of practice (C.P. 1011) on the maintenance of electric-motor control gear has been published by the British Standards Institution, and should prove of great value to all concerned with the maintenance and management of electrically powered industrial plants. The code provides guidance on those matters which experience has shown to be of major importance in keeping electric-motor control gear in efficient working condition. The various statutory regulations with which electrical installations may have to comply are indicated, together with such important general matters as inspection, observance of manufacturers' instructions, and the analysis of faults. An important section deals with the safety of personnel operating the installation, and emphasises such important precautions as isolation before maintenance work is carried out, the use of voltage indicators, special precautions in dealing with oil-immersed equipment, and the maintenance of earthing connections. Notes are included on first-aid and fire extinguishing equipment.

The main section of the code sets out general principles of maintenance, which are applicable to most types of equipment, followed by detailed recommendations for various types of control gear such as contactors, drum controllers, overload and time-delay devices, liquid starters and controllers, push button and similar auxiliary devices, isolators and composite units of switches and fuses. There is a useful list of special equipment that may be needed for carrying out the recommendations of the code. This code may be obtained from the British Standards Institution, British Standards House, 2 Park Street, London, W.1, price 6s.

Power Supply in Sweden

The Swedish State Power Board and the Swedish Water Power Association have collaborated in the publication of a fascinating illustrated booklet entitled "Power Supply in Sweden." The structure of the electricity-supply industry in Sweden is concisely explained, and the activities of the co-operating organisations outlined. Hydro-power resources are estimated to total 200,000 GWh, of which 80,000 GWh are worth exploiting and 33,900 GWh have already been developed. Installed capacity up to the end of 1960 was 6,900 MW of hydro and 2,000 MW of thermal power. After mentioning these and other interesting items of information the booklet deals in turn with each of the 12 main power-producing rivers, giving in each case a skeleton map showing the existing and projected power plants, a brief description of the river's development, and a table of the stations with their heads, capacities, year of commissioning, and owners. Brief sections are also devoted to thermal power, transmission and distribution, international power exchanges, and present and future consumption requirements. Altogether, the booklet gives a great deal of useful information in a concise and easily digestible form.

The Development of The Ume River

When fully harnessed, the Ume River in the north of Sweden will produce 7,800 GWh on the main watercourse in an average year. This first article describes the plans for developing the headwaters and the construction on the upper part of the main watercourse

PART ONE

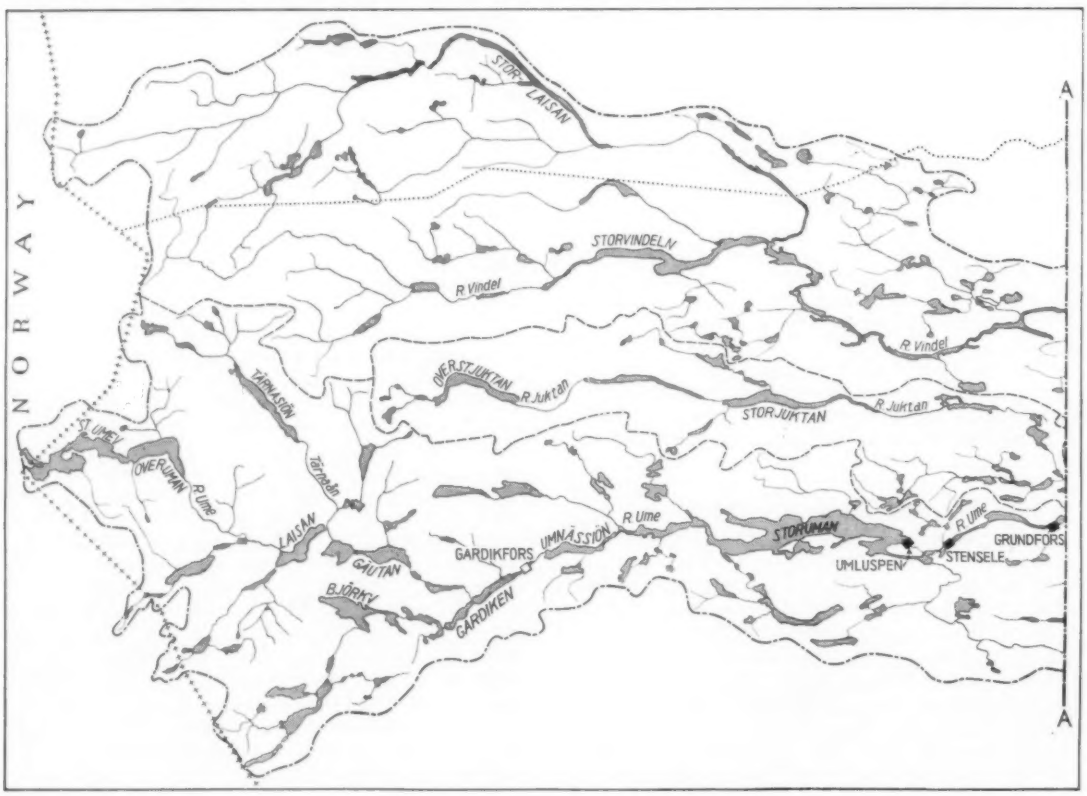
ON the basis of average flow the Ume is Sweden's fifth largest river and is one of the country's major sources of power. The river having the largest flow is the Göta, with 575 m^3/sec; this is followed by the Lule with 510 m^3/sec, the Ångerman with 490 m^3/sec, and the Indal with 460 m^3/sec. The average flow of the Ume River is 442 m^3/sec.

Although, from this standpoint, the Ume River is outclassed by other Swedish rivers it is a major source of power, and when fully developed should be able to produce 7,800 GWh in an average year on the main watercourse and 11,000 GWh if the Viadelälven tributary be included. Indeed, it feeds Sweden's largest power station at Stornorrfors, which has a present installed capacity of 375 MW and an ultimate capacity of 500 MW.

The Ume River is situated in northern-central Sweden and flows in a south-easterly direction to discharge into the Gulf of Bothnia at the town of Umeå. As will be seen from the map, Fig. 2, its headwaters are furnished by a complex of lakes reaching to the Norwegian frontier and discharging to Lake Storuman, roughly one-third of the way down the catchment, which forms the principal regulator for the main watercourse. A left-bank tributary, the Juktån, enters between Grundfors and Rusfors, and between Pengfors and Stornorrfors is the confluence with the Vindel, which also enters from the left. The Vindel is the chief tributary, and in fact, is nearly as large as the Ume itself.

The total catchment area above Stornorrfors is about 26,500 km^2, and in its natural state the river had an exceptional flood flow of 2,860 m^3/sec, a normal high-water flow of 1,800 m^3/sec, an average flow of 442 m^3/sec, an average winter flow of 236 m^3/sec, and a dry-year winter flow of 155 m^3/sec. With a storage of 1,390 million m^3 the exceptional flood will be reduced to 2,450 m^3/sec and the dry-year winter flow increased to 185 m^3/sec.

Development of the river is being carried out mainly by the Swedish State Power Board, but two important stretches are being exploited by private interests. Most of the stations on the main watercourse below Lake Storuman are now either com-



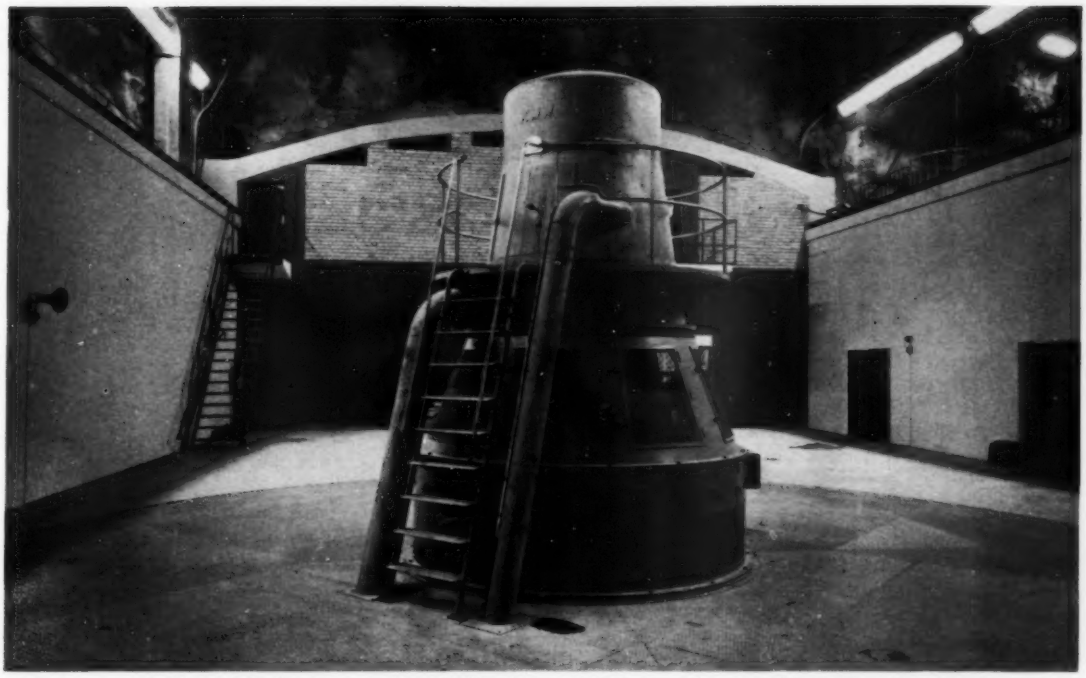


Fig. 1. Umluspen machine hall—the uppermost station on the main watercourse

pleted or in an advanced stage of construction, and future construction will concentrate on the upper reaches of the river above this lake.

Upper Ume Scheme

The scheme for the upper Ume is mainly in the project stage, but Gardikfors station, which the Swedish State Power Board has commenced to build is indicated on the map, Fig. 2. Seven stations are envisaged, giving an annual production of 1,265 GWh, and a storage of 2.250 million m^3 will be provided by eleven lakes. The proposals are subject to Government approval, and would take about ten years to complete.

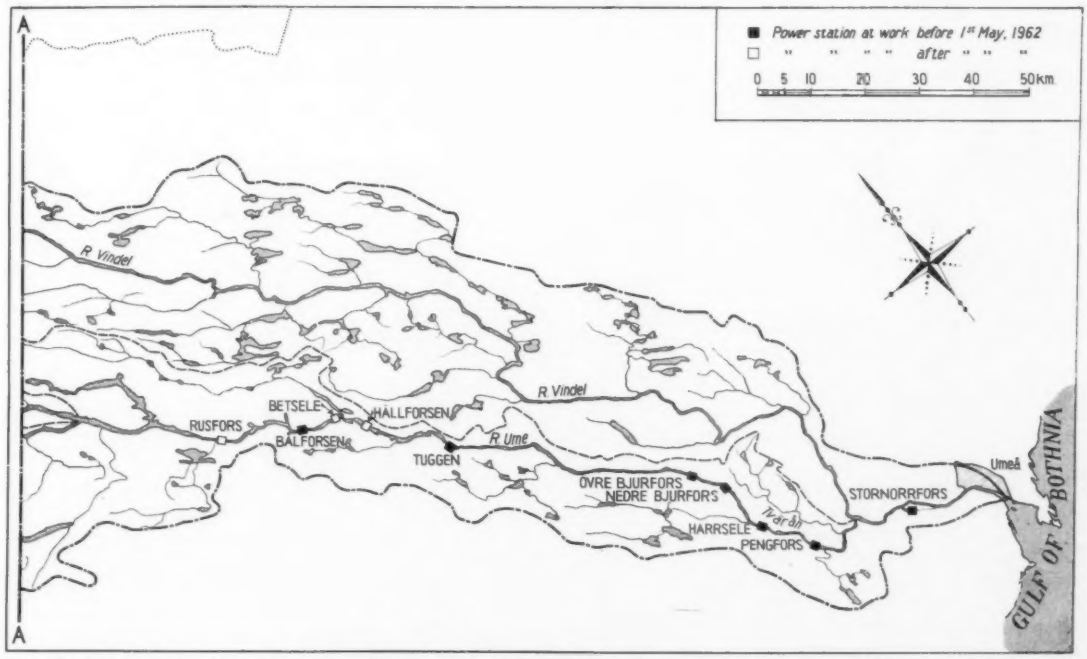


Fig. 2. Map of the Ume River catchment showing existing and proposed power station, including those owned by the Swedish State Power Board and by private interests

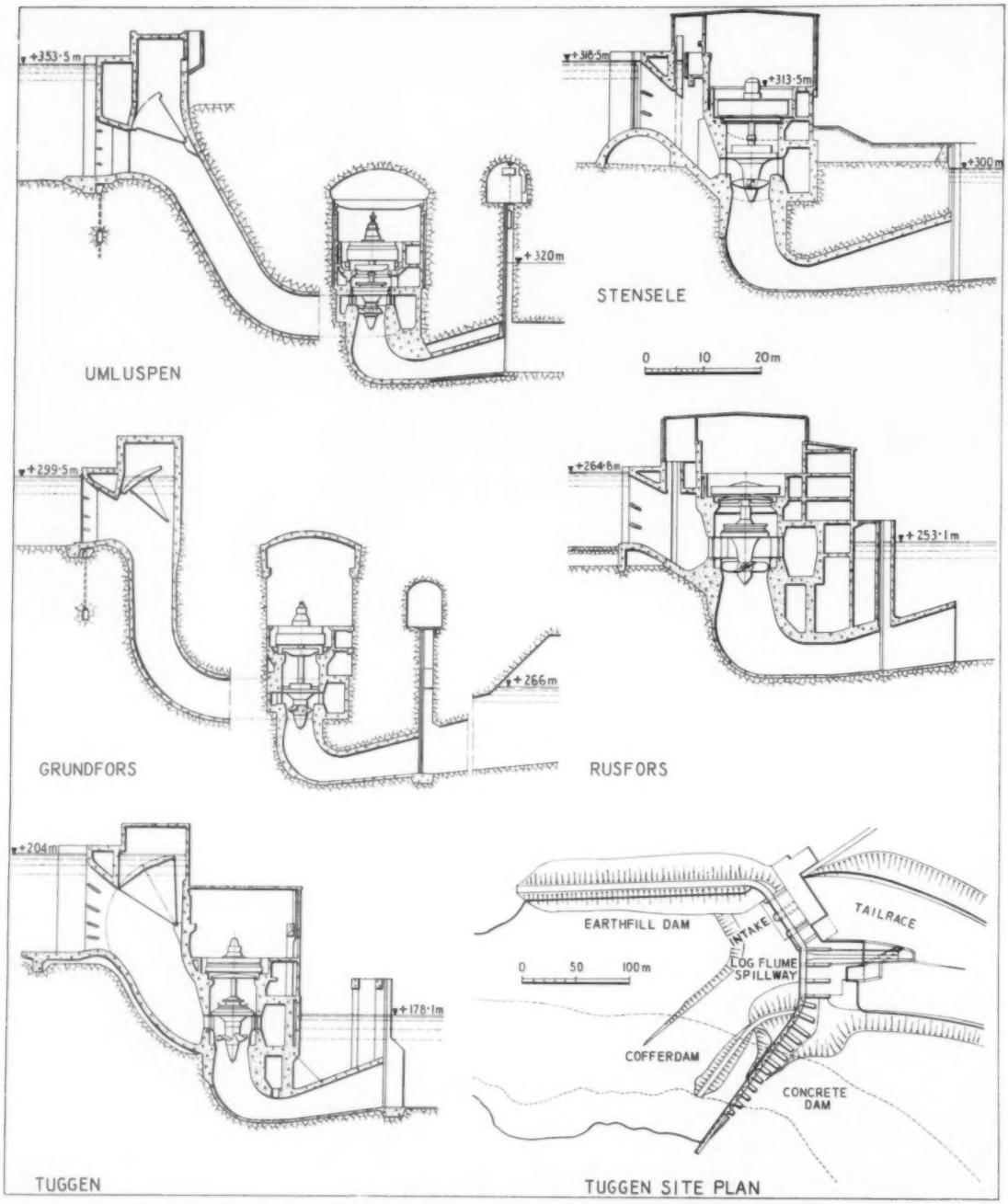


Fig. 3. Comparative cross sections through the State Power Board's stations on the Ume

At the time of writing, construction is in progress on the station farthest downstream—Gardikfors. Two earth dams totalling 1,100 m in length will raise the level of Lake Gardiken by 18 m, which, in conjunction with Övre Björkvattnet immediately upstream, will provide a storage of 875 million m^3. Gardikfors station will be of the underground type and have space for two Kaplan units of which one, with a capacity of 51 MW, will be installed in the first instance. A tailrace tunnel 500 m long is to be driven, succeeded by a channel 5 km long dredged in the river bed. Construction of this channel will involve the removal of 300,000 m^3 of rock and 1,600,000 m^3 of earth. Draglines of 6 m^3 and 3 m^3 capacity will be used to remove the earth and 2 m^3 shovels for the rock.

Main Watercourse

The main watercourse is being developed partly by the State Power Board and partly by private

Fig. 4. Umluspen machine hall under construction, showing the walls cast with sliding forms

companies. The upper part of the watercourse is under the control of the Board, who are exploiting it by a group of four stations—Umluspen, Stensele, Grundfors and Rusfors. Below Rusfors is a private station, Bålforsen, owned by Bålforsens Kraft AB, followed by sites secured at Betsele and Hällforsen by Korsselbränna Kraft AB. A single State Power Board station at Tuggen separates these stations from a second group of private stations under the control of Harrsele AB—Upper Bjurfors, Lower Bjurfors, Harrsele and Pengfors. Finally comes Sweden's largest station, Stornorrfors.

In the present article we propose to give a brief account of the Swedish State Power Board stations from Umluspen to Tuggen. A comparison of the cross section through the various stations is given in Fig. 3 and reveals, as one would naturally expect, a certain family resemblance in their design. Being low-head installations, Kaplan turbines are the rule. For heads above 20 m the water entry is controlled by a tainter gate leading to a penstock shaft, which in the case of the highest-head station, Grundfors (35 m head), is vertical. Below 20 m, as at Rusfors (11·8 m) and Stensele (19 m), the entry to the spiral is more or less direct and is controlled by a vertical sluice gate. An intermediate case is to be found at Tuggen (26 m) where there is no penstock proper, but the entry is deep enough to admit the use of a tainter gate.

Another point of interest is that concrete spirals are used throughout, and that in the more recent stations they are of prestressed construction. Within appropriate limits of head and diameter a concrete spiral is not only cheaper in itself than a steel scrollcase but it opens the way to economies in building construction. Thus, it is possible to obtain the desired water capacity by increasing the depth rather than the diameter of the spiral; the machines can therefore be placed at closer centre distances and the length and width of the machine hall correspondingly reduced. A particularly interesting case is to be noted at Rusfors (Fig. 3), where the concrete spiral extends beyond the downstream wall of the machine hall and is supported over the draft tube by a heavy concrete wall. The roof of the draft tube takes the thrust from this wall and also bears the weight of the annexed rooms and stoplog gantry; it therefore takes the form of a massive concrete beam.

The two highest-head stations—Umluspen (33 m) and Grundfors—are underground. Umluspen (Fig. 3) was the first State Power Board station in which the walls of the machine hall were constructed by the sliding-form method.* The crane runways are placed centrally on the tops of the walls, the usual heavy pillars and beams being unnecessary, as each wall forms a homogeneous monolith anchored to the rock. At Grundfors, on the other hand, the machine-hall walls are bare rock, and the crane runways are integral with the concrete roof arch and are anchored to the rock by prestressed rods.

Prestressed fabricated concrete elements are used

* See "Sliding Forms for Concreting," by Gunnar Pira, WATER POWER, January 1961, p. 18.

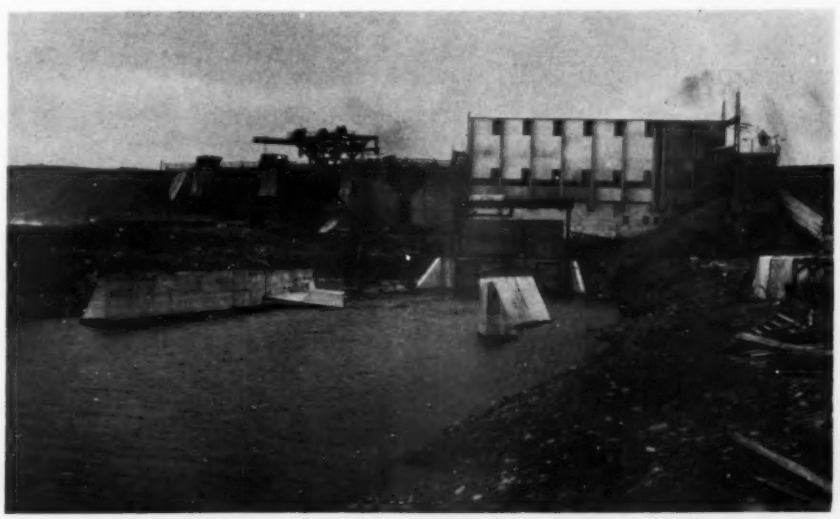


Fig. 5. Exterior view of Stensele station nearing completion

extensively in the construction of the buildings of the various stations.

Umluspen

Lake Storuman forms the regulating storage for the main watercourse, and Umluspen, as the uppermost station, naturally controls the regulation. The surface of the lake has been raised from a natural average water level of 349·0 m to 352·0 m and a drawdown to 345·0 m is possible, giving a live storage of 1,100 million m^3.

In point of fact the power station is about 5 km east of the regulating dam, which spans the original river bed at the outlet from the lake, the sluices being remote controlled from the station. This dam is of earthfill construction, with a moraine core, and is 1,000 m long at crest and 12 m high above lowest foundations. It has a central concrete spillway, with two 17·5 m wide openings controlled by tainter gates, and one 5·5 m wide opening controlled by a downward-opening sector gate. When fully opened the combined discharge is 1,450 m^3/sec at full retention level.

Raising the lake level has called for an earth dam adjacent to the power station 500 m long by 8 m high, and a low side dam 1,200 m long of sheet-pile construction. This dam cuts off a small arm of the lake which has been converted into a municipal bathing pool.

The power station has been sited so that its headrace and tailrace cut across a neck of land between an arm of Lake Storuman and a small lake in the Ume watercourse. A supply canal 680 m long was cut from the lake to the station intake to give a channel area of 200 m^2 at minimum water level, and a tailrace tunnel was driven 200 m^2 in cross section and 2,000 m long, succeeded by a tailrace canal 1,430 m long. These works, as well as the two penstock shafts, which are 7 m in diameter, were designed for a maximum flow through the station of 300 m^3/sec. Cutting the supply canal involved the removal of 280,000 m^3 of gravel and moraine and 50,000 m^3 of rock, the corresponding figures for the tailrace canal being 380,000 m^3 and 150,000 m^3.

Two 44-MW 0·9-p.f. KMW/ASEA vertical Kaplan generating sets are installed in the underground power station, running at 150 r.p.m. under a maximum gross head of 35 m and capable of generating 400 GWh in an average year. A single 110-MVA three-phase transformer, in a chamber adjoining the machine hall, steps up the power from 12·4 to 151 kV to feed a 130-kV line to Grundfors, and an auxiliary three-winding regulating transformer furnishes local supplies at 45 kV and 400 V.

A log flume capable of transporting 12,000 logs per hour follows roughly the course of the hydraulic circuit of the power station. An intake near that of the power station admits the logs to a canal, 200 m long, cut in the rock and leading to a flood river bed through which the logs float a distance of 1,800 m. Thence a canal 1,200 m long leads to the lake into which the power-station tailrace discharges.

Umluspen station, a view of which is given in Fig. 1, has been in operation since July 1957.

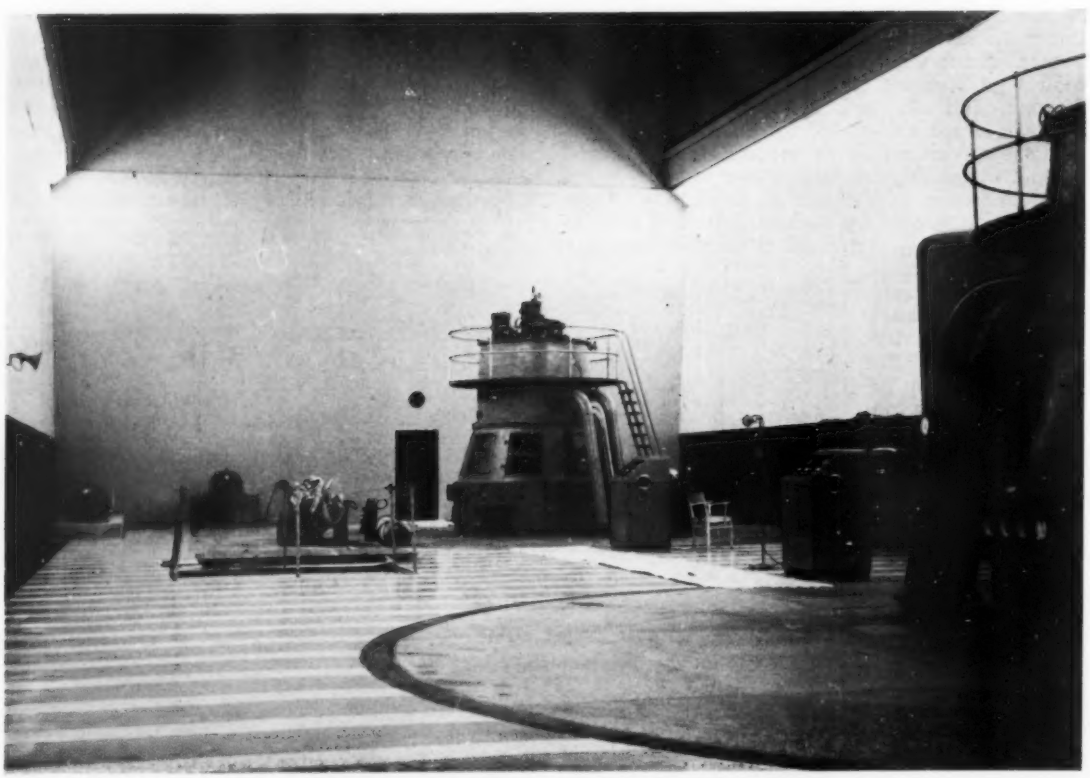


Fig. 6. Grundfors machine hall, containing two 44-MW Kaplan sets

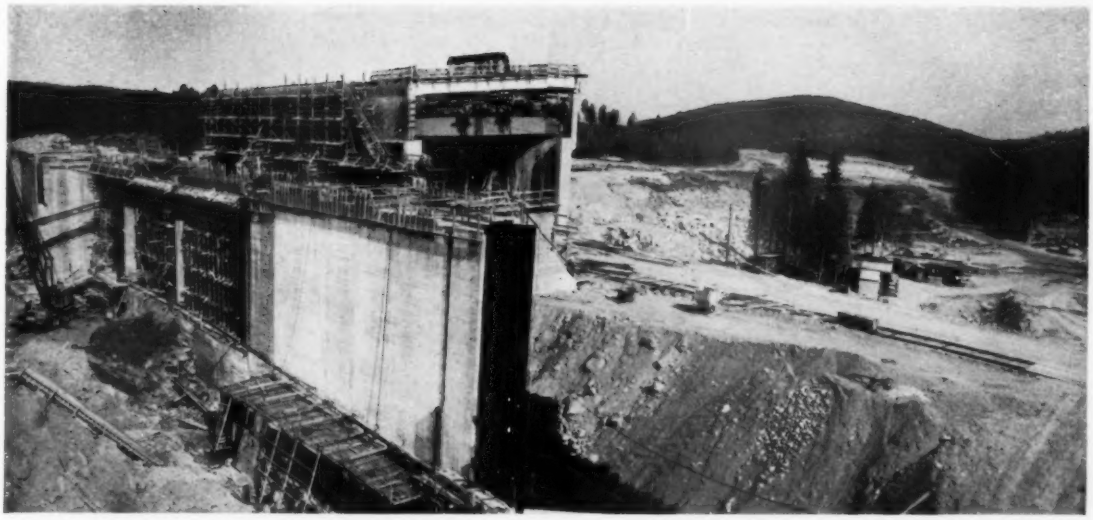


Fig. 7. Construction of intake structure, machine hall, and earthfill dam at Rusfors power station

Stensele

When we visited the site, Stensele station was in course of construction but it has recently come into operation. It possesses a single 48-MW set, the turbine having been built by Finshyttans Bruk, Filipstad, and the generator by ASEA. It utilises a flow of 300 m^3/sec under a head of 18·3 m, and can generate 230 GWh in an average year.

The station is placed in the centre of the river bed and is flanked on either side by an earth dam, each flank being about 600 m long. The rock substratum forming the foundation of the river bed dips from the right to the left bank and is covered by a sand and gravel deposit. At the power station the rock is 8 m below the surface, and under the left-hand dam it descends to a depth of 15 m. To reduce leakage under the dam through the pervious material in the left bank it has therefore been necessary to lay down a moraine blanket on the river floor upstream of the dam. On the right bank the dam is founded on impervious moraine. The dam itself has a maximum height of 23 m.

A tailrace canal, 900 m long, has been cut by a 3 m^3 Bucyrus Erie dragline, involving the removal of 300,000 m^3 of gravel and 40,000 m^3 of rock, and 8 km downstream, at Nysele, a further 1,700 m channel was cut by a 6 m^3 Marion 7,400 dragline, involving the removal of 600,000 m^3 of gravel and 50,000 m^3 of rock, and resulting in a gain of head of 5 m.

The power station is built in reinforced concrete and is faced with aluminium plate. To save building costs it is provided with a semi-portal-type crane, and a shackle permits the top of the runner to be lifted up between the crane girders.

Stensele station feeds into the 130-kV line from Umluspen, and is remote controlled from Grundfors 45 km downstream.

Grundfors

At the site of Grundfors station the main watercourse has been sealed off by a rockfill dam with a sloping moraine core, this dam having been built under the protection of a cofferdam of similar construction. The dam is 480 m long and 4·9 m wide at crest, is 25 m high over lowest foundation, and required 275,000 m^3 of rock and 125,000 m^3 of moraine and filter material. While the dam was being built the river was diverted through a channel 540 m long, which required the blasting of 52,000 m^3 of rock. This channel, which was cut in the right bank, was subsequently used as the spillway channel. The spillway has three openings, each 12 m wide, capable of a combined discharge of 1,500 m^3/sec.

To the left of the main dam is the power-station intake which supplies an underground station (Fig. 6) cut in the rock under the left bank of the river. From the station the discharge is led through a tailrace tunnel, 120 m long and 260 m^2 in cross section, to a tailrace canal 380 m long and 175 m^2 in effective area at a discharge of 300 m^3/sec. The rock quantities involved in the construction of the power station, tailrace tunnel and tailrace canal were 90,000, 41,000 and 105,000 m^3 respectively.

A log flume, the intake of which is immediately to the right of the station intake, discharges into the tailrace canal and can pass 10,000 logs per hour.

About 2·5 km below Grundfors it was necessary to cut a channel 3,550 m long between Grundfors and Mejvan ponds. This had the effect of lowering the tailrace level by 9 m and gaining a corresponding head.

Grundfors power station contains two Finshyttans-Bruk/ASEA 44-MW vertical Kaplan sets running at 150 r.p.m. and operating under a gross head of 33·5 m. In an average year the station can produce 400 GWh. The machines generate at 12 kV and feed a bank of three single-phase ASEA transformer units, a fourth unit being capable of connection into any phase. Grundfors picks up the 130-kV power from the up-river stations and also forms a feeding point for the 380-kV system. This transformer bank is therefore of the three-voltage type, giving three-phase voltages (in star) of 389/148/12·4 kV, corresponding to capacities of 165/125/2 × 30 MVA. A 60-MVA reactor is connected to the bars of each generator, and an auxiliary regulating transformer is also installed to furnish local supplies at 40 kV and 400 V. All the transformers and reactors are

housed in an underground gallery leading off from one end of the machine hall. An outdoor switchyard is located on the left bank of the river.

Rusfors

Rusfors station is now in course of construction and is scheduled for completion in 1963, first power being generated at the end of 1962. The generating plant will consist of a single KMW/ASEA 38-MW Kaplan unit operating under a net head of 11·8 m at a maximum flow of 380 m³/sec and having an annual output of 200 GWh.

We have already commented on an interesting feature of the design of the station in that the concrete spiral casing, as seen in Fig. 3, extends below and beyond the downstream wall of the machine hall. This spiral, in fact, is one of the largest in Sweden, and probably in Europe, being about 25 m in diameter.

The station is located some 300 m to the right of the natural river bed, and is succeeded by a tailrace channel 1½ km long cut mostly in earth. A spillway and log chute on the left of the power house will also discharge into the tailrace channel, and extending from the left of the spillway will be the main dam. This will be of earthfill construction with a moraine core, and will be 450 m long by 21·5 m in maximum height. As the underlying rock dips towards the left bank a moraine blanket is being laid on the upstream side of the dam. To the right of the power station is a side dam, also of earthfill construction. It is 18·5 m high, and the moraine core is carried down to bedrock.

The location of the main works to the right of the river is making it possible to construct the power station, spillway, tailrace, right-bank dam and most of the main dam in the dry.

Bålforsen, Betsele and Hällforsen

Below Rusfors is a privately owned station, Bålforsen, the property of Bålforsen Kraft AB, a subsidiary of Svenska Cellulose AB. It has been constructed for three generating sets, two of which have so far been installed. With the two machines the station capacity is 83 MW and the normal annual output 500 GWh.

The natural water level at the site has been raised 19 m by a concrete buttress dam (Fig. 8), 530 m long and reaching a maximum height of 32 m. It has a spillway section with two tainter gates and one downward-opening sector gate, having a total discharge capacity of 2,050 m³/sec. A log chute, 300 m long, discharges into the tailrace canal. Three intakes provided with tainter gates (the gate for the future third set has not yet been installed) admit to steel-lined penstock shafts leading to an underground machine hall.

The two generating sets consist of KMW 51,000 h.p. Kaplan turbines running at 150 r.p.m. under a net head of 31 m and coupled to ASEA 50-MVA generators supplying power at 8·7–9·6 kV. Each generator supplies a 50-MVA transformer stepping up to 120 kV and located in an outdoor switchyard. The transformers and other electrical equipment are also of ASEA manufacture.

The water is restored to the river through a 110-m long, 270-m² section tailrace tunnel followed by a 400-m tailrace canal. By blasting and dredging the river bed at two narrow sections an additional head of 3 m was obtained.

The consultants for the civil-engineering project and design and for the mechanical equipment were Vattenbyggnadsbyrån (VBB), Stockholm, and the electrical consultants were Bergman & Co. AB, Stockholm. The civil-engineering contractors were AB Skånska Cementgjuteriet.

Fig. 8. Bålforsen buttress dam. The power-station intakes can be seen in the background

Fig. 9. Construction work in progress at Tuggen

Below Bålforsen are the Betsele and Hällforsen sites owned by Korsselbränna Kraft AB. Work is shortly to be started at Betsele, where a 24-MW station containing two units operating under a head of 9·5 m is to be built. At Hällforsen construction work has already commenced on a two-unit station of 19 MW operating under a head of 7·7 m. The consulting engineers for both of these stations are VBB, Stockholm.

Tuggen

At the time of our visit the Swedish State Power Board's station at Tuggen was under construction but it was expected to commence generation at about the time this article appears. As will be seen from Fig. 3, the layout of the development is somewhat unusual as the retaining works are roughly U-shaped in plan. A concrete buttress dam, 190 m long and 26 m high above lowest foundation, spans the river bed and joins the spillway and log-flume block at the left bank. Beyond the log flume is the power-house intake structure, which is set at an upstream angle to the spillway block, and the barrage is completed by an earthfill dam 240 m long by 26 m high above lowest foundation, which extends in an upstream direction roughly parallel with the river. A channel is cut in the bank to give the necessary depth in front of the spillway and power-house intake, and a tailrace canal receives the discharges from both the power house and the spillway block.

The positions of the concrete and earthfill dams, of course, were determined by the topography of the site, and the angling of the spillway and intake structures was determined by model tests to give the most efficient flow pattern through the plant.

The spillway has two openings. The left-hand one was provided with a bottom outlet to divert the river through the tailrace canal while the central section of the concrete dam was built and to get better flow to the log intake when the power station is shut down; the rest of the works were previously built in the dry.

It was found from model tests that if the log flume were operated while the power station was shut down, an eddy would form which would carry the logs round in front of the draft-tube outlets. To prevent this a channel, seen in Fig. 3, was cut from the stilling pool of the left-hand spillway opening, passing beneath the log flume, and discharging diagonally across the tailrace canal.

To cut the tailrace canal the overburden was removed by a Ruston Bucyrus 38 excavator, and the underlying rock was drilled by a battery of four caterpillar-mounted Atlas Copco BBC42 chain-feed machines using 1¼ in extension steels. The rock is a granite and required 0·25–0·30 m of drilling and 0·35 kg of explosive per cubic metre of rock. Spoil was removed by a Ruston Bucyrus 54 shovel assisted by some small Åkerman shovels. Below the tailrace canal a channel 5 km long had to be dredged in the river bed by a 6 m³ Marion 7,400 walking dragline assisted by a 3 m³ Bucyrus Erie dragline.

The construction of the Tuggen development has called for the heaviest earthmoving programme of any of the State Power Board stations on the Ume, the total cubage being no less than 3,200,000 m³, thus exceeding Stornorrfors, which required the removal of 2,850,000 m³, of earth. Tuggen has also entailed the highest cubage of concrete—57,000 m³ as against 56,000 m³ for Stornorrfors.

The power station (Fig. 9) has been built to house two NOHAB/ASEA 48-MW Kaplan sets operating under a head of 25·5 m and having a combined discharge of 420 m³/sec. Space has been left to extend the power station to accommodate a third set. On the basis of two machines the station can produce 420 GWh in an average year.

(To be continued)

Flow Problems in Pipes

A direct method is presented for solving the flow problems in pipes in cases when the flow is partially as well as fully turbulent

By B. P. SANGAL*, M.Sc.

THE three simple flow cases that are usually encountered in the solution of pipe-flow problems are:

Given:	1. D, L, Q, ν, ϵ	To determine:	h_f
,,	2. h_f, L, D, ν, ϵ	,, ,,	Q
,,	3. h_f, L, Q, ν, ϵ	,, ,,	D

where D = diameter of the pipe
L = length of the pipe
Q = discharge
h_f = loss of head
ν = kinematic viscosity
ϵ = absolute roughness of the pipe.

The variables L, ν, ϵ are always known. For solving these problems, usually the Darcy-Weisbach equation

$$h_f = f \frac{L}{D} \frac{V^2}{2g}$$

the continuity equation

$$Q = \frac{\pi}{4} D^2 V$$

and the Moody diagram are used. It is well known that the cases involving the determination of Q and D are fairly complicated, and the trial-and-error method is adopted to arrive at a reasonably accurate solution. The method suggested here avoids the direct use of the Moody diagram. The solutions of all three types of problems enunciated above can be found easily.

According to the Darcy-Weisbach relation we have

$$h_f = f \frac{L}{D} \frac{V^2}{2g}$$

$$\text{or } 2g \frac{h_f}{L} = f \frac{1}{D} V^2$$

Multiplying both sides by $\frac{\epsilon^3}{\nu^2}$ we have

$$2g \frac{\epsilon^3}{\nu^2} \frac{h_f}{L} = f \left(\frac{\epsilon}{D}\right)^3 \cdot \frac{V^2 D^2}{\nu^2}$$

$$= f \left(\frac{VD}{\nu} \cdot \frac{\epsilon}{D}\right) \cdot \left(\frac{\epsilon}{D}\right)^3 \cdot \left(\frac{VD}{\nu}\right)^2$$

$$= F \left(R, \frac{\epsilon}{D}\right)$$

Thus the group $2g \frac{\epsilon^3}{\nu^2} \cdot \frac{h_f}{L}$ is a function only of Reynolds number and the relative roughness. This function has been plotted against Reynolds number for various values of $\frac{\epsilon}{D}$, as shown in the accompanying chart. The values of f were taken from the Moody diagram. An average curve is shown separating the partially turbulent flow from the fully turbulent flow.

The solution of the three types of problems can be explained thus:

1. *To Determine the Loss of Head*
From the given values calculate:
(a) The Reynolds number.
(b) The ratio $\frac{\epsilon}{D}$.
(c) The term $2g \frac{\epsilon^3}{\nu^2}$.

Corresponding to these values, find $\frac{h_f}{L}$ and, hence, h_f.

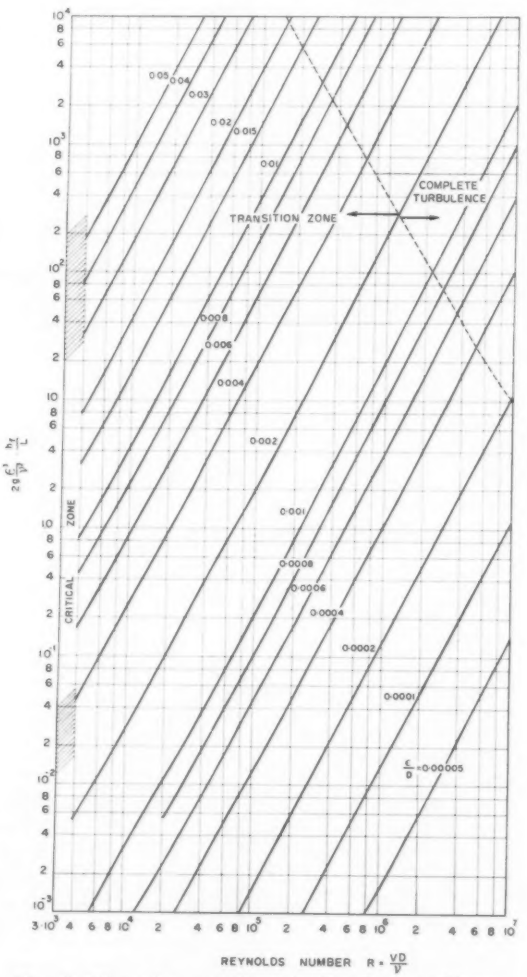


Fig. 1. Chart for solution of pipe-flow problems

* Graduate Research Assistant, Department of Civil Engineering, Queen's University, Kingston, Ontario, Canada.

2. *To Determine the Discharge*
From the given values calculate:

(a) The term $2g \frac{\epsilon^3}{\nu^2} \cdot \frac{h_f}{L}$.

(b) The ratio $\frac{\epsilon}{D}$.

Corresponding to these values find the Reynolds number and, hence, V. Apply the continuity relationship to find the discharge.

3. *To Determine the Diameter of the Pipe*

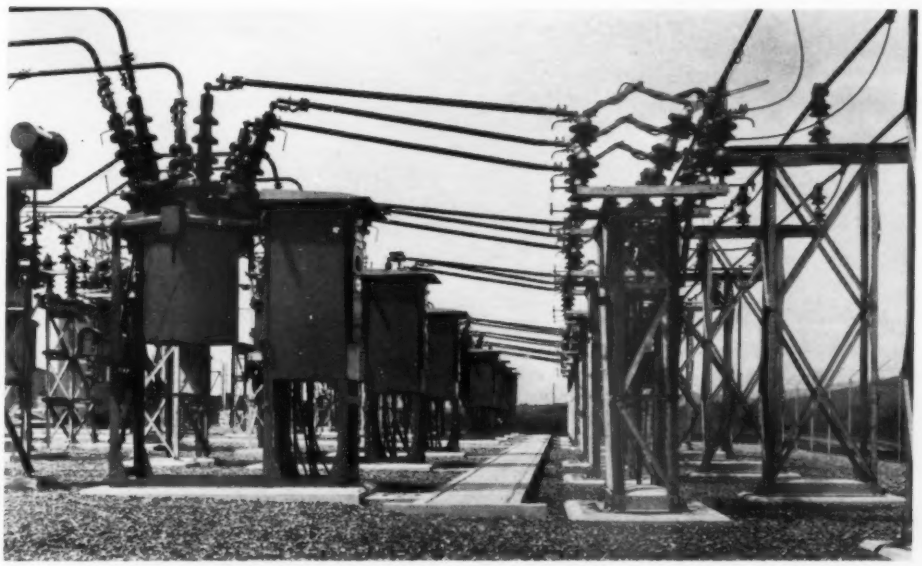
(a) Calculate the term $2g \frac{\epsilon^3}{\nu^2} \cdot \frac{h_f}{L}$.

(b) Assume an approximate value of D.

(c) Find $\frac{\epsilon}{D}$ and the Reynolds number.

(d) Apply the method of trial and error to make the values agree.

Substation in the Scottish Highlands



South Wales Switchgear equipment at Taynuilt substation

South Wales Switchgear Limited, of Blackwood, Monmouthshire, has completed the design and erection of Taynuilt substation to the order of the North of Scotland Hydro-Electric Board to handle the output from their Inverawe generating station, now under construction. This substation, which was initially linked to the public-supply system in April, includes 33-kV oil circuit breakers, voltage transformers, overhead busbars with supporting insulators and all the supporting steel structures, together with the necessary 132-kV air-break isolators and fault-throwing switches and 33-kV isolators. A suite of 132-kV and 33-kV control and relay panels and a complete low-voltage a.c. switchboard are also provided. In addition, South Wales Switchgear Limited has supplied and laid the complete station multicore cabling and earthing system.

The Taynuilt layout is a seven-circuit single-busbar arrangement, comprising two 132-kV incoming transformer feeders, one 33-kV incoming feeder from Inverawe, and four outgoing 33-kV feeders providing reinforcement to the Oban, Connel and Clachan areas. Space is provided for the addition of future bus-section oil circuit breakers and additional feeder circuits. Inverawe station will generate at 11 kV, stepping up to 33 kV and feeding direct via overhead line for threequarters of a mile to Taynuilt substation. The two 132-kV infeeds are brought from Inverary substation on Loch Fyne across fifteen miles of difficult country.

South Wales Switchgear has additional work in hand for the installation at a later date of full supervisory control equipment and automatic synchronising facilities.

33-kV Cables for Welsh Hydro Station

Two mass-impregnated non-draining three-core 33-kV power cables, specially manufactured by the Power Cables Division of British Insulated Callender's Cables Limited to withstand stresses arising from installation on a steep gradient, have been installed by British Insulated Callender's Construction Co. Ltd. as part of the Cwm Rheidol hydro-electric scheme, 12 miles inland from Aberystwyth in the Welsh mountains. The 4½-in diameter MIND cables were manufactured in lengths of 1,800 ft, each weighing over 20 tons. Two steel-wire armoured PVC pilot

cables have also been supplied as part of the contract.

The power and pilot cables are secured in shaft-type cleats bolted to a concrete slab formed in the bottom of a trench. They are installed on a 1,380-ft long slope at an average angle of 32° from horizontal. Before the ground is reinstated, the cables will be protected with inverted concrete troughs for which anchor recesses have been provided in the concrete slab. Provision will also be made for natural ventilation. The cores of the 0·5 in² conductors in each cable are individually sheathed with lead to provide additional strength and for convenience of terminating in sealing ends at each end of the route.

Because of the weight of the cables and the steepness of the slope, installation posed a number of engineering problems. The drums could not be taken closer to the top of the hill than 250 yards, from which position the cable had to be drawn across a boggy field and lowered down the slope by two winches running simultaneously, wire bonds being attached at a succession of points. A hand winch at the bottom of the slope was used to guide the cable end to the transformer enclosures. The main winch used for lowering was equipped with a torque converter which enabled the heavy cable to be inched into the correct position for anchorage in teak cleats.

When the power station is commissioned the cables will carry its total output from step-up transformers to connect with a 33-kV overhead line at the top of the hill. The Cwm Rheidol power station, which is being built for the Northern Project Group of the Central Electricity Generating Board, draws its power from waters in the Welsh hills and discharges into the Afon Rheidol which runs into the sea at Aberystwyth.

Kennedy & Donkin, Consulting Engineers, are responsible for the transmission installations associated with the scheme.

Tractor-Mounted Compressor

Atlas Copco recently introduced their tractor-mounted compressor, known as the Roughrider. The unit consists of a Fordson Major tractor carrying an air-cooled two-cylinder reciprocating compressor of the type used in two existing Atlas Copco machines, the VT4 portable and the TT6 skid-mounted stationary compressors. The compressor is driven from the power take-off of the tractor, and delivers 140 ft³/min at pressures up to 100 lb/in². The accompanying illustration shows the Roughrider during trials at Traprainlaw Quarry, East Lothian, Scotland.

Atlas Copco Roughrider tractor-mounted 140 ft³/min air compressor

New Crowd System on Smith "21" Excavators

Thomas Smith & Sons (Rodley) Ltd. announce the introduction of a new auto-positive dual crowd system on their Smith "21" excavators, which has the effect of providing additional biting power with marked simplification of the control. The hoist rope is spooled on the compensating drum to give automatic crowd action, and the new system is said to incorporate all the advantages of both the automatic rope crowd and the orthodox positive crowd systems. There is single-lever control of the shovel bucket with automatic crowding action and positive crowd action of the bucket arms in all positions. The hoist rope compensation allows in-line crowding and dual-crowd action can be applied when necessary.

Terrax Protective Coatings

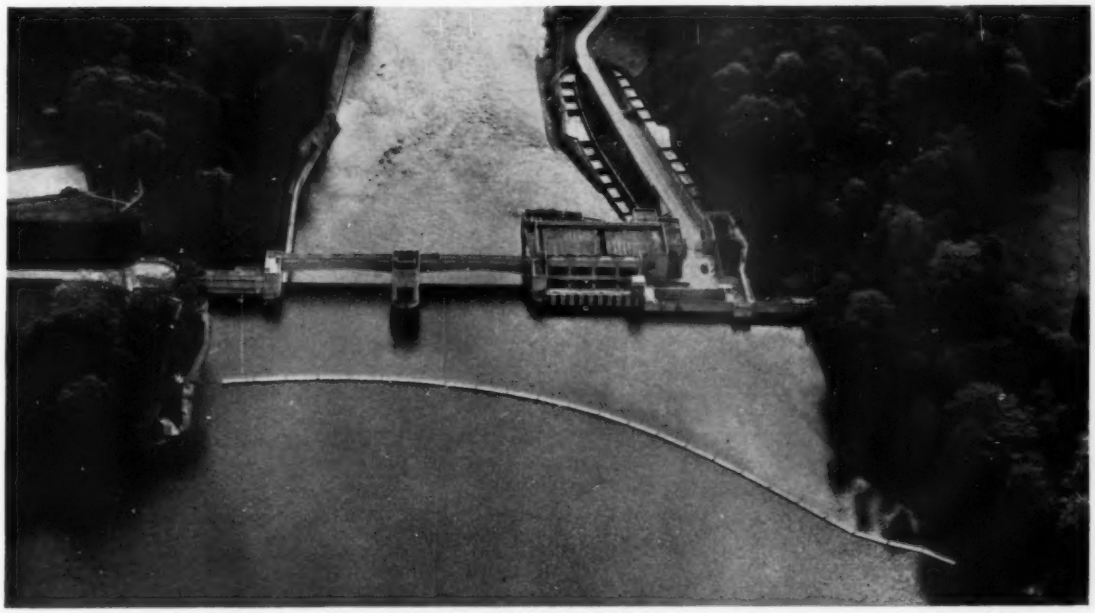
Robert Bowran & Co. Ltd., Pelaw, Gateshead 10, England, have recently given details of their Terrax protective coatings. The standard grade is said to be a water-resisting and water-setting composition, which is primarily designed for application to areas subject to inundation, where adequate ventilation and prolonged drying cannot be provided. It forms a hard black film and is claimed to have excellent anti-corrosive properties. It will withstand temperatures up to 120°F although it is not specially a heat-resistant paint.

A high standard of surface preparation is preferable prior to application, which consists of only one coat. The coating is said to dry in 24 hours when immersed in water, or in approximately 48 hours when air dried. Although the coverage rate depends on the condition of the steel surface, estimates may usually be based on 150 ft²/gal.

The heavy-grade coating is a modified version of the standard grade, and is specially designed to withstand conditions such as those experienced in surge tanks, i.e., aerated turbulent water. It is said to withstand temperatures of up to 180°F, and to have a maximum coverage rate of 100 ft²/gal.

The third Terrax coating is known as E grade, and is a blend of epoxy-resin/coal-tar pitch, designed for use in highly corrosive conditions where conventional paint treatment cannot be recommended. The success of this coating depends to a large extent on the surface preparation, and it is vital that the surfaces are clean, dry, and free from millscale and rust. A grit- or shot-blasted surface is regarded as being essential. The coating dries in air in about 24 hours, and in about 16 hours under water. Drying can be accelerated by the application of heat, but maximum hardness is not reached for about 7–10 days, irrespective of the drying method. It is recommended that the material should be applied at the rate of 120–125 ft²/gal, which will result in a thickness of approximately 0·010 in. It is suggested that two coats should be applied.

Floating Aluminium Boom at Pitlochry



The welded aluminium boom at Pitlochry power station

An interesting feature of the North of Scotland Hydro-Electric Board's Tummel-Garry project is the floating boom in Loch Faskally, just upstream of the Pitlochry dam (see WATER POWER May–June, 1951). The boom is designed to prevent floating material blocking the turbine-intake screens. The structure, which is 600 ft long, was built by Non-Corrosive Metal Products Limited, West Drayton, Middlesex, England, who specialise in aluminiun-alloy fabrication. The boom consists essentially of 24 light-alloy pontoons, which are linked together, and anchored at each end to the shore and at four other points offshore. Provision has also been made for opening a section of the boom if required, so that accumulated debris can be disposed of by sluicing it away over the spillway.

The pontoons were assembled by Argonaut welding, and each pontoon consists basically of two rows of three watertight compartments approximately 7 ft long by 1 ft 10 in wide and 10 in deep, formed from ¼-in thick plate. Three removable skirts are fitted on the upstream side of each pontoon, and these are made of 10-gauge flanged aluminium-alloy plate, and are designed to intercept debris. On the top of the pontoons is a walkway made of extruded Duratread, which is said to be self-draining and to have excellent grip even under icy or slimy conditions. The aluminium alloys used in this assembly were all supplied by The British Aluminium Company Limited.

The use of aluminium alloys in various forms for this structure is said to have been dictated by the inherent resistance of the material to attack by acid water and by the elimination of any need for painting. Furthermore the use of aluminium alloy was clearly of assistance in providing increased buoyancy.

The boom was launched by Balfour Beatty & Co. Ltd., and the consulting engineers to the NSHEB for this project are Sir Alexander Gibb & Partners of London.

Improved Nuclear Device for Measurement of Soil Properties

The TESTlab Corporation, of Chicago, Illinois, U.S.A., have announced that they are now marketing an improved nuclear device for the measurement of soil moisture content and density. The principles on which the apparatus works are not claimed to be new, but it is stated that the new product is only about 60% of the weight of other available equipment. The device employs radioactive sources of low activity and, as far as the USA is concerned, does not require to be licensed.

New Concrete Additive

A new liquid additive which is said to give extraordinary workability characteristics to concrete is now on the British market. The additive allows a substantial reduction to be made in water content during mixing and at the same time plasticises the concrete to a uniform quality. It is marketed under the registered name "Flocrete" and has been produced by Quickset Water Sealers Limited. The makers state that independent tests prior to marketing have shown that by using this plasticiser the design strength of a structure can be achieved with a cement content up to 20% lower than specified. The compressive strength of hardened concrete can be increased by up to 25%, and its bond strength to steel by up to 20%. For mass

and reinforced-concrete work the plasticiser increases workability up to 150%, allowing larger pours and easier finishing. The controlled workability together with water reduction give a wider choice of mixes and materials to designers and contractors.

Book Reviews

Ausfluss, Überfall und Durchfluss im Wasserbau. By F. H. Knapp. Published by G. Braun, Karl-Friedrich-Strasse, 14 18 Karlsruhe, Germany. 1960. 700 pp., 410 ff. Price DM 78.

The English translation of the full title of this book (which was written mainly for water-power engineers) might be "flow through openings, over weirs and under gates of hydraulic structures: Applied fluid mechanics." The author is the head of the design and construction division of the largest hydro-electric company in Brazil and Professor of Hydraulic Engineering at the Mackenzie University, São Paulo, and quotes a home address on the shore of Lake Constance. As expected, the book is a careful study, based largely on Central-European and American experience and reading, of a field chosen narrowly enough to permit a great deal of detailed description, explanation and discussion, with design exercises covering 200 pages throwing additional light on the theoretical part.

Part I contains the material that would normally be expected in a work intended both as a textbook and as a handbook. After an introduction in the first chapter, setting out the author's general views on the present state of the subject, he deals in chapter II with units both fundamental and derived, with dimensional analysis and dimensionless parameters, with similarity and with model laws. The 66 pages of chapter III deal in considerable detail with curved flow, especially the free vortex, flow through curved open channels and closed conduits (including reference to secondary flow and to separation), the hydraulic jump, backwater and drawdown curves, the abrupt drop at the end of a channel, and—too briefly—with models constructed with vertical distortion. Chapter IV, in 100 pages, covers the flow through orifices, pipe entries, butterfly and needle valves, and under flat and sector gates, with some reference to vibration and cavitation. The free ("modular") flow over fixed weirs is studied in chapter V, and drowned flow in chapter VI, both dealing with a variety of profiles. These chapters start with a description of the current methods of analysis of weir flow, and rightly reject what Professor Knapp calls the "Poleni-Weisbach" approach, still too often found in text-books. In its place he advocates the use of the rigorous hydrodynamic picture which, after all, has been known amongst advanced students for over half a century. As weir flow is a part of the elementary hydraulics syllabus as prescribed for students in all branches of engineering, it seems that chapters V and VI especially might be read with profit by the appropriate examiners. (Advanced students should then go on to more general treatments as sketched in Charles Jaeger's and Ven Te Chow's books.)

Chapter VII describes the treatment of (usually sharp-edged) weirs shaped to vary the head/discharge relation for a special purpose. Examples are the V-notch, the parabolic weir, and the proportional (Sutro) weir. In view of his earlier criticism, it is surprising that Professor Knapp in this chapter bases a good deal of geometrical and analytical development on the Poleni approach. This involves him in the use of Beta and Gamma functions, but in the end he has to fall back on empirically determined coefficients of discharge (including coefficients of velocity and contraction). He quotes a simple basic formula, the coefficients and indices in which may be found in a simple table—a result which he could have obtained by the direct application of the principle of mechanical similarity described in his chapter II.

The last two chapters, VIII and IX, of Part I deal with flow over and under flow-control gates of many kinds. In both Professor Knapp makes use of flow nets (as he might have done in the study of flow over round-crested weirs in chapter V). He even introduces potential and stream functions, although they do not serve any practical purpose in what follows. His flow nets are checked by constructing diagonals and drawing inscribed circles, in accordance with the methods of F. Prasil and S. Leliavsky.

The practical part of chapter VIII describes flow patterns, pressures and discharges under sector (tainter) gates, over bear-trap, drum, and flap gates, and over and under double vertical lifting gates. Chapter IX contains information on coefficients of velocity, contraction and discharge for flow under vertical and inclined plane gates and under sector gates, with the width of the downstream channel equal to or less than that of the approaches, and with the jet either free or submerged. Although mention is made in chapter I of boundary-layer suction, no reference appears in chapter IX to boundary layers, and their effects seem to be rather unsatisfactorily attributed, at least partly, to "dead water" upstream of control gates. Chapter IX also treats the hydraulic jump in uniform and non-uniform channels, compares results of model tests with those of computation, contains useful diagrams for various shapes and sizes of gate openings, and introduces, with a discussion, a neat classification of forms of underflow.

Part II contains twenty exercises of considerable practical importance, most of which are given a full treatment. The first six are applications of free-vortex theory to flow measurement and to the design of syphons, draft tubes, and drop shafts. The theory of flow through orifices, nozzles, and valves is applied to seven exercises, on the determination of leakage and on the design of the governing gear for the needle valve of a Pelton turbine, of the oil valves of servomotors, of an energy dissipator for a tunnel, and of the outlet through a flood-storage dam. Weir discharge problems appear in connection with the design of various types of flood spillways for reservoirs and cofferdams. Flow under a gate appears in an interesting design of a constant-level control system and in the analysis of the suction acting on the underside of a gate.

As was indicated earlier, Professor Knapp has rendered great service to the student of engineering hydraulics, firstly by collecting a body of theory and empirical data, and secondly by describing the paths to a logical understanding of flow: the recognition of the physical factors influencing a flow pattern, the dimensional analysis of the parameters into which

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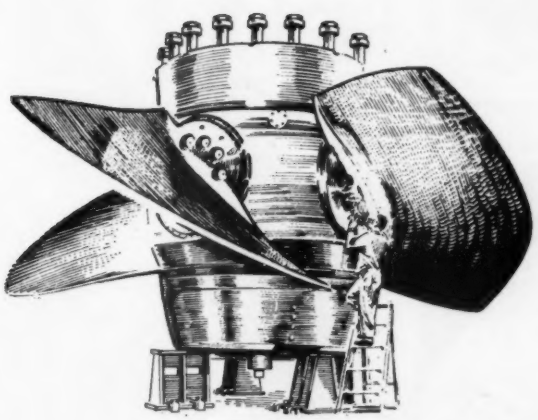

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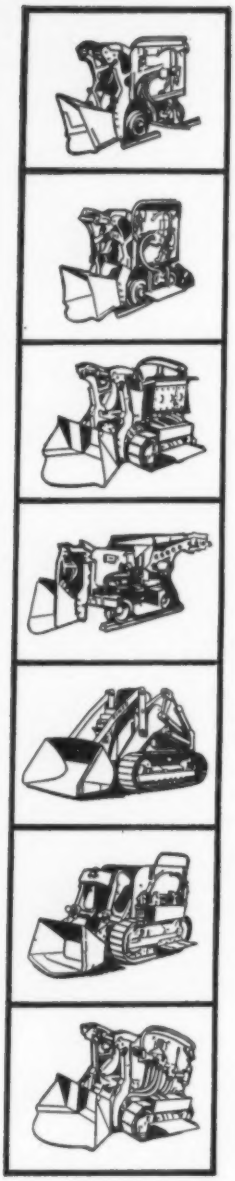

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these factors are grouped, rigorous mathematical treatment of the flow equations based on the laws of mechanics, and estimates of errors due to our inability to achieve exact solutions of these equations. At the same time, the reader brought up on the works of Osborne Reynolds, Lord Rayleigh and Sir Horace Lamb (the last does not even appear to be mentioned!) may regret a certain lack of elegance and, indeed, deeper perception which in recent years have been such a pleasure to see in the papers of Jack Allen and C. M. White in Britain, of A. T. Ippen and Hunter Rouse in the United States, and of Charles Jaeger—to mention but a few of the men who may be considered capable of dealing with the author's subject. Even so, the student able to read comparatively simple, lucid German will find the book a useful supplement to his basic studies of fluid mechanics. Most practising engineers engaged in the design of hydraulic structures and of water-control devices will greatly benefit from the collection of data and examples.

The book is excellently produced, with illustrations and tables so organised as to be both clear and of immediate practical use, and with a remarkably small number of errors. All coefficients, where they contain dimensions, are of course in metric units.

Recent Technical Achievements in Constructing Large Dams. A complete English edition of the special number of *Travaux*, Vol. 45, No. 319, May 1961, published on the occasion of the Seventh International Congress on Large Dams by Editions Science et Industrie, 6, Avenue Pierre-Ier-de-Serbie, Paris, 16e; 288 pp., 324 ff. Price, bound in soft covers, NF. 35.

This is essentially a survey of French engineering practice in the building of large dams. In view of the many outstanding achievements of French dam builders in recent years, the selection of articles for this bulky issue must have been difficult and the editors deserve full credit for the way in which they have solved the problem. All the structures described and discussed are typical examples of the class of dam they represent. The choice of Marckholsheim (Rhine), Saint-Vidian (Garonne), Baix-le-Logis-Neuf (Rhone) and Truel (Tarn), could hardly be bettered as far as run-of-river installations are concerned, and the same applies to earthfill dams (Serre-Ponçon, Malemale), spillway-type gravity dams (Golinhac), buttress dams (La Raviège), intake dams (Raschas), and others. The book is divided into four main sections: EDF developments in Metropolitan France; developments effected by Compagnie Nationale du Rhône; and two sections on Algeria, one dealing with the Upper Oued Djen-Djen scheme by Electricité et Gaz d' Algérie, and the other devoted to three developments by the Algerian Department of Hydraulic and Rural Equipment. Four articles on French projects either completed or nearing completion in other parts of the world are appended. To single out any particular structure included in this survey would be a difficult task; however, we should like to draw attention to a few articles of particular technical interest, such as "Concreting Work, its Control, and Sealing Up of Foundation Rock at Roselend Dam," by J. P. Lajeat and J. Orth, p. 21; "Comprehensive Survey of the Serre-Ponçon Project," by M. Guelton, P. Baldy and C. Magne, p. 58; "Calculating the Surge Tank of the Mansouria Underground Plant," by E. Meneroud, p. 211; "Concrete Cooling at Dokan Dam, Iraq," by P. Fouillade and C. Wilhelm, p. 261. We should not like to close this review without mentioning the moving tribute paid in the preface to the late M. André Coyne, the designer of the Roselend, Kariba, and many other great dams, by M. Marcel Mary, President of the French Committee on Large Dams.

NOTE: "La Technique Française des Grands Barrages" is the original French edition of the publication reviewed here, and although the number of pages is larger, the content of technical matter is the same as in the English version. Price in France, 25 NF.

Trade Publications

Mobile Cranes. Ransomes & Rapier Limited, Ipswich, England, have sent us a copy of their publication No. 3/494, which describes the Rapier 6 and 7 Standard mobile cranes. Full details are given of the performance and dimensions of these machines, which are claimed to be exceptionally manoeuvrable.

Pyrotenax Limited, Hedgeley Road, Hebburn-on-Tyne, Co. Durham, England, have produced a handsome brochure to mark the twenty-fifth anniversary of the company. The publication describes the many applications to which Pyrotenax cables have been put, and emphasises their fireproof and other properties.

Blaw Knox Limited, Rochester, Kent, England, have issued a detailed booklet describing their AP-100 concrete-mixing plant, which incorporates either one or two Gyramixers. When arranged with two of these mixers, an output of 100–120 cu yards/hour is said to be maintained. The plant is normally arranged for air-assisted manual control.

Vermiculite Handbook. This interesting publication is a 40-page pamphlet dealing with the many uses of vermiculite, and is produced by Mandoval Limited, 59 Gresham Street, London, E.C.2. The mineral is a member of the mica family and has found many applications especially in the fields of insulation and fire protection. An example is quoted of its use as a thermal insulator for a high-altitude dam in Italy, in order to prevent spalling at low temperatures.

Power Construction Limited, of 7–17 Jewry Street, London, E.C.3, is a consortium of British companies, which has been formed to design, manufacture, deliver and construct power stations in any part of the world. A well-illustrated brochure has been issued that describes the activities of the component companies, who are The Armfield Hydraulic Engineering Co. Ltd., Belliss and Morcom Limited, Cory Brothers and Co. Ltd., Lancashire Dynamo Holdings Limited, and Mitchell Engineering Group Limited.

Liquid Earthing Resistors. A new publication, Technical Description No. 475, issued by the Engineering Group of the General Electric Co. Ltd., Erith, Kent, England, describes the company's range of liquid earthing resistors. These are available in seven sizes, and are designed for indoor and outdoor use. The ratings vary from 600 A at 6·6 kV to 900 A at 66 kV. The pamphlet describes the construction of this equipment in some detail, and adequate performance data are given.

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Abstracts from the World Technical Press

Czechoslovak Advance in Water Turbines

The progress achieved by Czechoslovak engineering in the design and manufacture of water turbines is reviewed in this article, with separate sections for each of the three conventional types, and for reversible turbines. It is a far cry from the small machines occasionally turned out at Blansko, near Brno, in Prince Salm's inconspicuous workshops, which were subsequently taken over and enlarged by the Breitfeld-Daněk Company, and now form an important branch of the ČKD nationalised corporation, to the large turbines listed in this survey. Mention is made, for example, of eleven 59,700-h.p. Pelton units, now under construction, to operate from a 630-m head, and of a ten-blade 128,000-h.p. Kaplan machine, which is nearing completion, and is designed for a head of 44·0 to 70·5 m. In the field of Francis turbines, work is proceeding on three 8,000-MW hydro-electric projects, which will each comprise twenty 400-MW machines operating at 200-m head. The three projects are apparently similar, and three alternatives are under consideration with the aim of reducing the size, and more particularly, the length of the power stations. Although the first two alternatives are mainly variants of the position of the thrust bearings on the vertical shaft, the third possibility is a novel conception of Professor Nechleba, of Brno Technical University, in which two 4,400-mm runners are mounted on the shaft of each turbine. In this design, for which patent rights have been applied for, the speed will be increased to 214 r.p.m., and it is claimed that the space required for each unit will be reduced by 22%, the weight of the turbine and the generator being respectively 28–34% and 30% less. A final paragraph deals with pumped-storage plants and the problem of reversible turbines. Whereas prior to World War II, Czechoslovak turbine output was no more than 110 large units aggregating 390,000 h.p., production at the ČKD Blansko works has increased to date to 283 units with a total capacity of 2·5 million h.p. (Antonin Šamla, *Czechoslovak Heavy Industry*, English Edition, No. 5/1961, pp. 18–21, 4 ff.)

Pumped Storage and Steam Capacity Factor

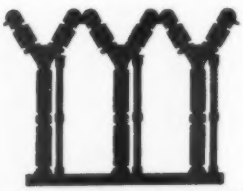
In this fairly short but quite comprehensive article, the author surveys the part played by pumped-storage plants in hydro-thermal generating networks in meeting system peak loads, and at the same time improving the thermal-plant capacity factors during off-peak hours. The progressive increase in the efficiency of thermal generation led US operators at first to disregard entirely any other type of peak-load generation, but many utilities are now investigating the possibilities offered by pumped storage in their system areas. Many feasible sites may be overlooked in the belief that sufficient head is not available in a certain area. Generally, from an economical standpoint, about 250 ft would be a minimum head for a pure pumped-storage project, although under certain circumstances this minimum could be lowered to substantially less than 100 ft in a system combining pumped storage with a conventional hydro-electric project. The author discusses pumped-storage project economics. One objection to pumped storage was that, contrary to thermal plants, it would not supply plant capacity on a 24-hour basis, but it is now realised that it should not be expected to operate in such a manner, its principal function being to furnish system peak-load capacity. In so doing it increases the capacity factor of the system's thermal units, and the load factor of the system. Finally, capacity requirements are reviewed. There is little doubt that the peak load of generating systems will grow as the system load grows. The worst thing that can be done is to accept only an expensive method of meeting these peaks. Accordingly, a bold and fresh approach is required, strengthened by a willingness to investigate a fundamental principle such as pumped storage as a means of meeting peak loads, and also as a means of loading thermal units at off-peak periods, thereby making full use of incremental economy energy. (H. S. Hunt, Jr., *Power Engineering*, No. 3, March 1961, pp. 45–47, 3 ff.)

Indus Basin Developments

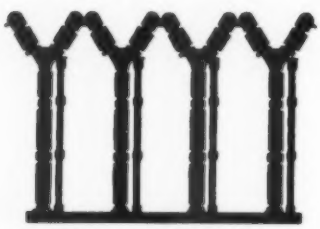
A comprehensive survey is made of the construction programme worked out by the Water and Power Development Authority of West Pakistan as a result of the Indus Basin Water Treaty (see Editorial, WATER POWER, November 1960, p. 413). The main hydro-electric project included in the programme is based on the Mangla dam, on the Jhelum River, a 75-million cu-yard earthfill structure, designed by Binnie, Deacon & Gourley, London, with a large concrete spillway of 1,200,000-cusec capacity, designed by Harza Engineering Company, Chicago. The 370-ft high dam will be located at a point where the river bends around a high rock promontory on its left bank (site of an old Mogul fort) and is confined on its right bank by a range of high hills. Its left-bank end will curve upstream behind the promontory, and the structure will extend for about 10,000 ft across the river bed and curve slightly downstream into the hills forming the right abutment, where the spillway will be sited. The intake on the left bank for the irrigation outlets and the power station will feed six 2,500-ft long tunnels. However, if studies now in progress establish the possibility of halving this length by a relocation of the inlet and outlet portals, the number of tunnels could be reduced to five, because of the lower friction loss in the shorter tunnels. In that case, the tunnels will connect through Y-branches to ten 100-MW generating units in the ultimate development. Discharge will be to an afterbay separated from the river by a low dam, over which the water will spill when it cannot be taken by the new irrigation canal, which also leads from the afterbay. The main spillway, a major structure requiring 30 million cu yards of excavation and 1 million cu yards of concrete, confronted its designers with the problem of providing a capacity of 1·2 million cusecs in a structure of reasonable width, which, it was decided, was about 500 ft. Model studies led to a solution with submerged openings with gates sited down in the body of the structure, so as to operate as submerged orifices under a head of about 100 ft. Another great irrigation-power development is planned at Tarbela on the Indus River. The main feature will be a rockfill dam.

▲ 72.5 kV – 3000 MVA sym

▲ 170 kV – 7000 MVA sym



▲ 245 kV – 10000 MVA sym



▲ 345 kV – 14500 MVA sym

▼ 420 kV – 17500 MVA sym

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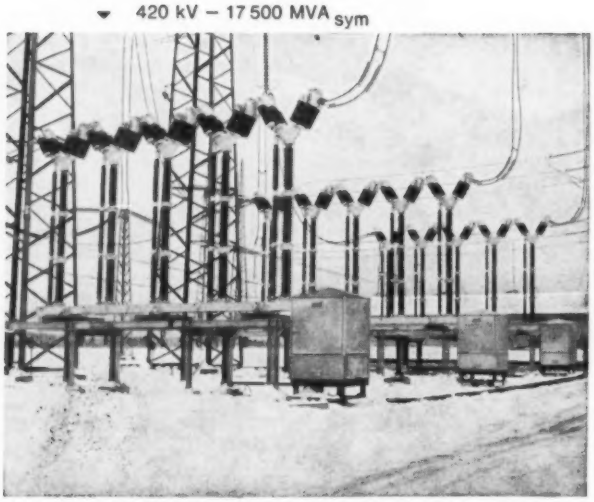

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100 million cu yards in volume, and possibly 130 million cu yards if an upstream blanket is adopted, which would make the dam the largest in volume in the world. Of the three sites initially considered for Tarbela dam, the one farthest downstream is now being given most attention. It would require a structure over 10,000 ft long and 340 ft high in the first instance, and provide the live storage prescribed by the treaty of 4·2 million acre ft, plus some extra for local irrigation. Owing to the potential storage of over 10 million acre ft at the site, the dam will probably be planned for future raising. One advantage of this site is that the natural valley on the left bank can be converted into a spillway discharge channel, and would also provide fill material for the dam. Preliminary studies suggest a 2-million-cusec spillway with twenty-six 50 by 40 ft gates operating under a 10-ft surcharge. Only the irrigation potential of Tarbela will be developed at the outset, but provision must be made for a future power plant. Power and irrigation intakes would be sited on the right bank, which is the only place where rock is near enough to the surface for economic foundations. Sixteen 23-ft-diameter pipes embedded in concrete and discharging a total of 100,000 cusecs would be installed, and, of these, ten would be available to feed the future power station. (Waldo G. Bowman, Editor, *Engineering News-Record*, Vol. 166, No. 6, February 1961, p. 30, 9 pp., 10 ff.)

Swedish 400-kV Transmission System

In this issue of the Blue-White Series of the Swedish State Power Board (English Edition), a detailed account is given of the extensive investigations carried out on the stability of the Swedish 400-kV transmission system. In view of the long transmission distances encountered in Sweden, stability is an important factor when planning the extension of the trunk-line network; the principles of planning are therefore quite different from those applying to ordinary distribution systems. Stability investigations were effected by conventional calculation as well as by means of network analysers, digital and analogue computers, and tests, both on small-scale models and in the field. So far, these investigations have been restricted to transient stability; some 1,100 swing curves have been calculated in this particular connection, most of them by means of analysers. Steady-state stability, however, is being given increased attention owing to the growing interconnection of the system; such stability problems, however, will have to be tackled by field testing as well. (B. Nordström, L. Norlin, R. Gradin and A. Olwegard, Swedish State Power Board, Stockholm, *Blue-White Series*, No. 28, 25 pp., 12 ff.)

Butterfly Valves

The extensive use in water engineering, particularly in connection with water turbines, of this type of shut-off valve, generally called a throttle valve in Germany, has given rise to many thorough investigations of their efficiency. In the first instalment of this article, the author deals mainly with the hydraulic properties of the butterfly valve, i.e., with the action of the flow on the disc and body of the fitting, reviews various designs of butterfly valves, and discusses their suitability under various sets of conditions. This study is based to a large extent on the tests carried out at Ateliers des Charmilles, S.A., Geneva (WATER POWER, December 1951, p. 456, and January 1952, p. 16). In the second instalment various typical examples of application are described and discussed with the aid of calculations and graphs. (Dipl. Ing. Walter Volk, *Die Wasserwirtschaft*, Vol. 50; October 1960, 9 pp.; November 1960, 8 pp.; 20 ff.)

Arch-Dam Analysis

The practical example of analysis reviewed and discussed in this paper applies to the Pontesei dam, a double-curvature arched structure built across the Maé, a right-bank tributary of the Piave River. The resulting Forno di Zoldo reservoir forms part of the well-known SADE Piave-Boite-Vaiont-Maé system. The dam, designed by Ing. Carlo Semenza, is 90·00 m in height, 150·205 m in developed crest length, and the ratio chord : height is 1 : 1·43. The concrete placed totals 63,640 m^3, and the rated capacity is the reservoir is 1 million m^3. The static analysis is first carried out by all the best-known methods (Guidi, Cain, Stucky, Kettner, Tölke and others) in which the structure is considered as consisting of independent resisting arch elements, and is followed by methods developed for space structures, i.e., systems of arch and cantilever elements (Ritter, Datei, Tölke, Arredi, Krall). A paragraph is devoted to a report on the model tests effected under the supervision of Professor Ing. Guido Oberti at Instituto Sperimentale Modelli e Strutture in Bergamo. The paper concludes with a comparative survey of the various methods applied in this investigation, mention being made, in connection with these methods, of certain assumptions regarding performance, which it may appear necessary or advisable to adopt. The importance of small-scale models tests as a reliable means of checking arch-dam analysis is stressed. (E. Indri, *L'Energia Elettrica*, Vol. XXXVIII, No. 2, February 1961, p. 97, 30 pp., 5 ff.)

Yugoslav Adriatic Developments

The 550-km Yugoslav Adriatic coast and its hinterland, from Rijeka to close to the Albanian border, is the original karstic region, characterised by highly fissured calcareous rock into which rainwater is quickly absorbed. It is, in fact, an eastern extension of the Italian Carso. In spite of abundant precipitation, there are only a few watercourses, and they are all relatively short and rather flashy in character, discharge being at its maximum mainly in winter, whereas the summer flow is almost negligible. This hydrological characteristic is of importance when considered in conjunction with the Drava regime, as the Drava River, the greatest source of energy in the north of the country, reaches its maximum discharge in the summer, following the thaw in the Alps. By co-ordinating in time the utilisation of both these sources of power, energy production could be balanced to a wide extent within a hydrographic year. Another advantage of the Karst-region resources is that reservoirs can be formed at very high levels, and at a relatively short distance from the sea, to feed power stations erected at practically sea level. This means that large storage facilities would enable almost the whole yearly discharge of the developed rivers to be harnessed for generation. The availability of the water at given times ensures the economic soundness of

these developments in spite of the considerable expenditure involved in thoroughly sealing up crevices in storage reservoirs. The total utilisable water resources of the Yugoslav Karst exceed by far the requirements of the country for many years to come, and their full development within the framework of a European schedule of production could later lead to the export of surplus winter energy in exchange for summer energy from the Alpine regions. This article concludes with a condensed survey of the Yugoslav Karst region's existing hydro-electric plants, and also those in course of construction or still at the project or planning stage. (Dipl. Ing. Stefan Szavits-Norsan, *Schweizerische Bauzeitung*, Vol. 78, November 3, 1960, p. 709, 5 pp., 4 ff.)

NOTE: Other references to this region appeared in the following issues of WATER POWER: February 1959, p. 79; March 1960, p. 123, and June 1960, p. 249.

EHV Test Line in Operation

A description is given of the seven-mile 460/500-kV transmission line built by TVA and put into operation at 161 kV in early February with a view to gaining design and construction experience, and to appraise the value of EHV transmission for the TVA system. This EHV section is inserted in a 52-mile 161-kV line connecting the TVA's 1,275-MW Johnsonville steam plant to its system at Lawrenceburg in middle Tennessee. The EHV section traverses terrain varying in elevation from 820 to 1,020 ft above sea level. The shortest span is 815 ft, the longest 2,216 ft. A total of 34 single-circuit, 460/500-kV steel structures are used, and 30 tangent and four small-angle (4°) structures. (K. E. Hapgood, *Power Engineering*, No. 3, March 1961, p. 48, 1 f.)

Grande Dixence Water-Collection System

This is a lecture given on November 19, 1960, at the Lausanne Technical University in connection with the Course of Operational Research organised by Société Vaudoise des Ingénieurs et Architectes. The 357-km² supply zone of the Grande Dixence Development is the area from which waters are diverted to fill the Val-des-Dix reservoir, and subsequently feed the Fionnay and Nendaz plants. Its main installations include, in addition to the intake structures and pumping stations, a 24-km long master supply tunnel and its lateral galleries, 25 km in total length; all the underground conduits are designed for free flow, with the exception of the two inverted syphons, 1,460 and 1,890 m long respectively, crossing the Z'mutt and Gorner dales, and, of course, the penstocks of the pumping plants, totalling 4,800 m. The average annual volume of summer water collected is 420 million m³, of which the portion contributed by the lowest glaciers —about half this amount—has to be raised again by the pumping plants. The author describes in detail the procedure applied in calculating the economic optimum for each section of the installation. In the case of the collection network, two graphs have been produced, both expressed in terms of the distance from the storage reservoir, of the additional cost of enlarging the main tunnel so as to cope with an additional discharge of 1 m³/sec from any point of the system, and the extreme length of the overflow periods of the balancing reservoirs attached to some of the pumping stations, in order to establish the most economic dimensioning of the various intakes. Special attention is devoted to the problem of economical dimensioning of steel-lined shafts, and it is extended to all cases of penstocks, concreted shafts, buried conduits, etc.; the specimen computation relating to a case of steel-lined shaft is given in detail. The Arolla and Ferpècle pumping plants operate in series, and the discharge calculations for the downstream station, Arolla, is reproduced in full. (Pierre Meystre, Chief Engineer, Grande Dixence S.A., *Bulletin Technique de la Suisse Romande*, Vol. 87, No. 9, May 6, 1961, p. 138, 10 pp., 5 ff.)

Deep Grout Curtain at Dillon Dam

Work on the foundations of the Dillon dam, which is 9,000 ft up in the Rocky Mountains and near Denver, Colorado, is now well advanced, and work has begun on the 15-million cu-yard embankment. The article describes the diversion of the Blue River through a 17-ft diameter tunnel, and the foundation work from the cut-off trench. Grouting for the cut-off curtain is performed in 80-ft. drill patterns, and end holes are drilled and grouted to 250 ft. The central hole on the 40-ft spacing is then drilled and grouted to a depth of 150 ft. Next, the two 20-ft spaced holes are also drilled and grouted 150 ft deep. The 80-ft pattern is then completed by drilling and grouting the remaining four 10-ft spaced holes, the depth of which varies with the acceptance in the other five holes, but is generally put down to 60 ft or more. The total number of grout holes to be drilled will be at least 500; some of those already completed have taken up to 3,000 bags of cement. Other phases of the work in progress, such as dewatering the cut-off trench, rock excavation, high-altitude earthmoving and tunnelling, are also described. Completion of the Dillon project is planned for November 1963. (*Engineering News-Record*, Vol. 166, No. 20, May 18, 1961, p. 67–70, 5 ff.)

Tidal-Electric Power Generation

The production of power from the ocean tides is an intriguing possibility and the author has contributed an interesting survey of developments in this field. The first part of his article describes the various features of ocean tides—and for engineers whose knowledge is confined to river regimes it may come as a surprise to learn that there are so many different patterns of tidal behaviour. Part II of the article deals with the various theoretical methods by which tidal power might be utilised, and then outlines the schemes that are now either under active consideration or, as in the case of the Rance project, under construction.

The proposed schemes include the vast Minquier Islands proposal by the French and the Soviet Arctic Circle project. Alternative schemes for the Bay of Fundy are considered in detail, and comparative operating data are given, although the economics are not discussed. The author's conclusions are given at length, and these emphasise two important advantages of tidal schemes over hydro schemes. First, the height and time of arrival of the tides and, therefore, the possible power available, can be predicted with fair precision far into the future. Second, tidal regimes are not affected by the flood and drought conditions that cause such seasonal variations in the flow of rivers. (F. Keith Dalton, *Journal of the Royal Astronomical Society of Canada*, February and April, 1961, 27 pp., 10 ff.)

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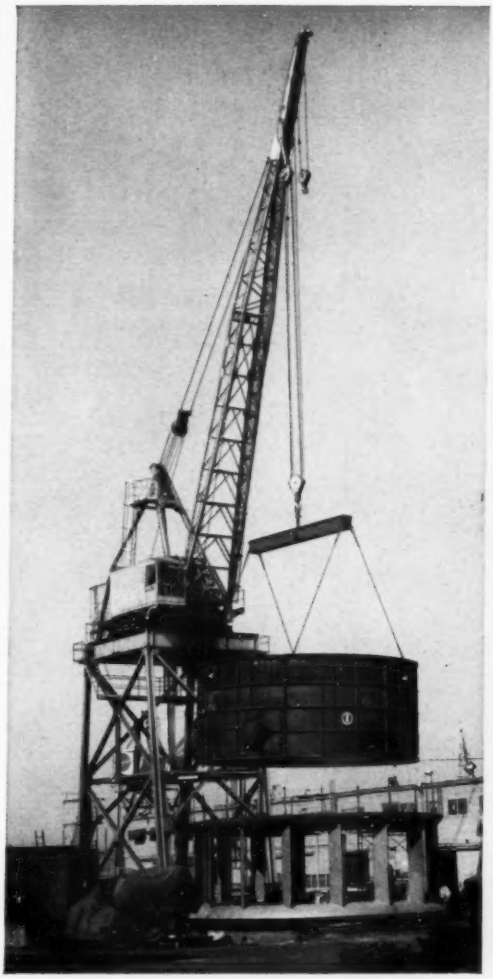

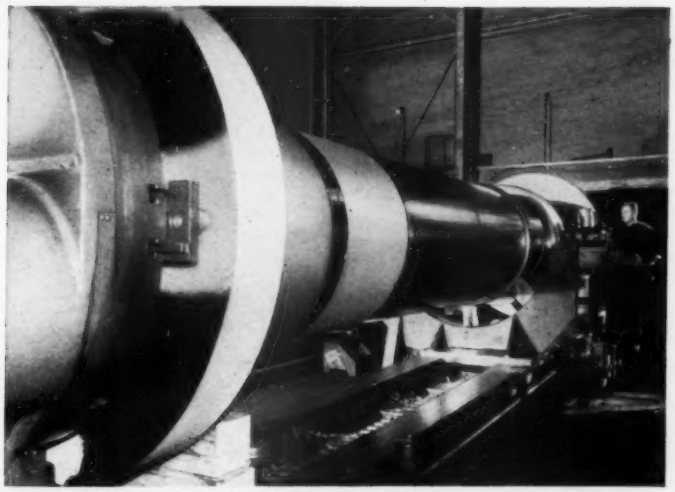

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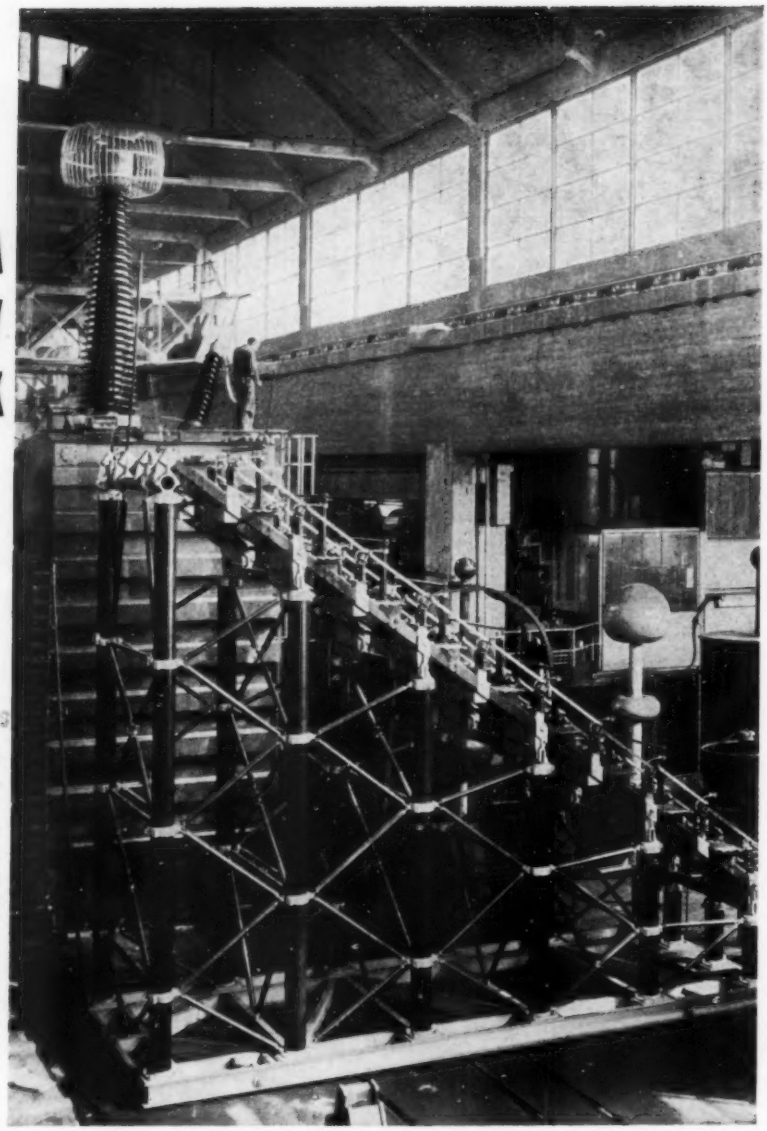

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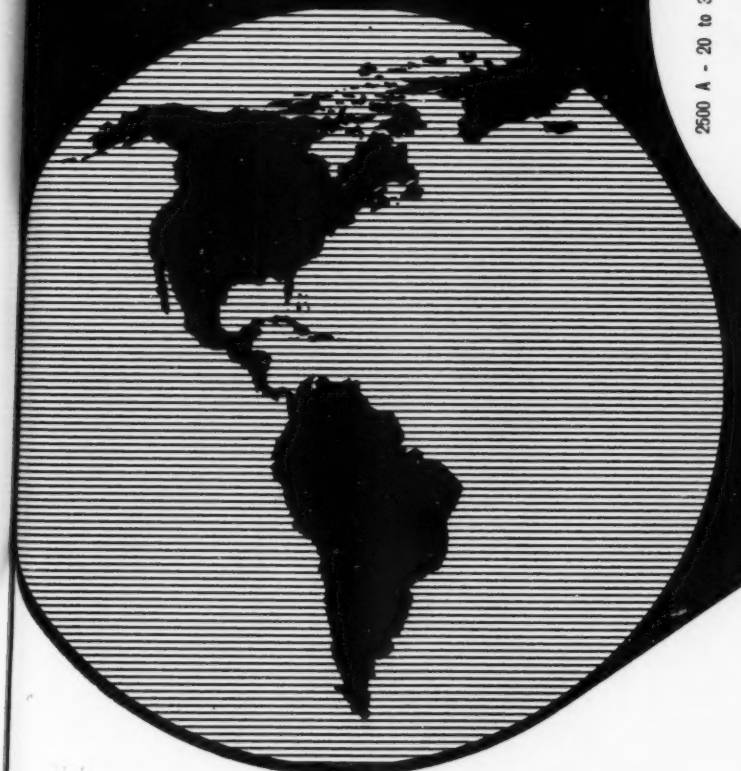

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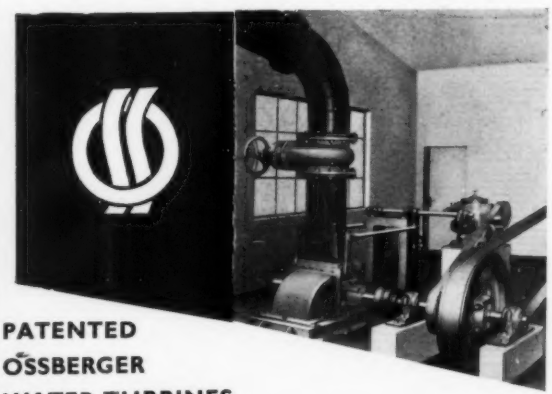

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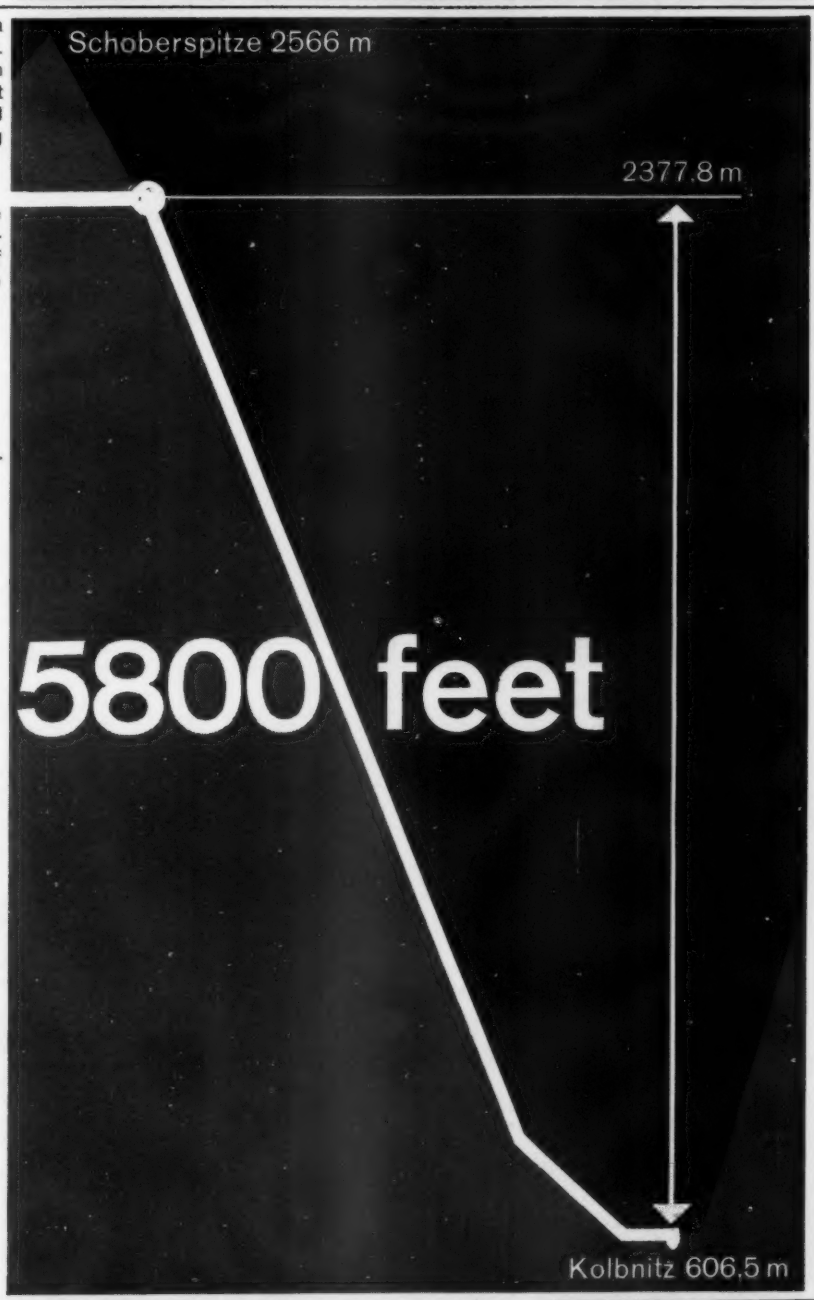

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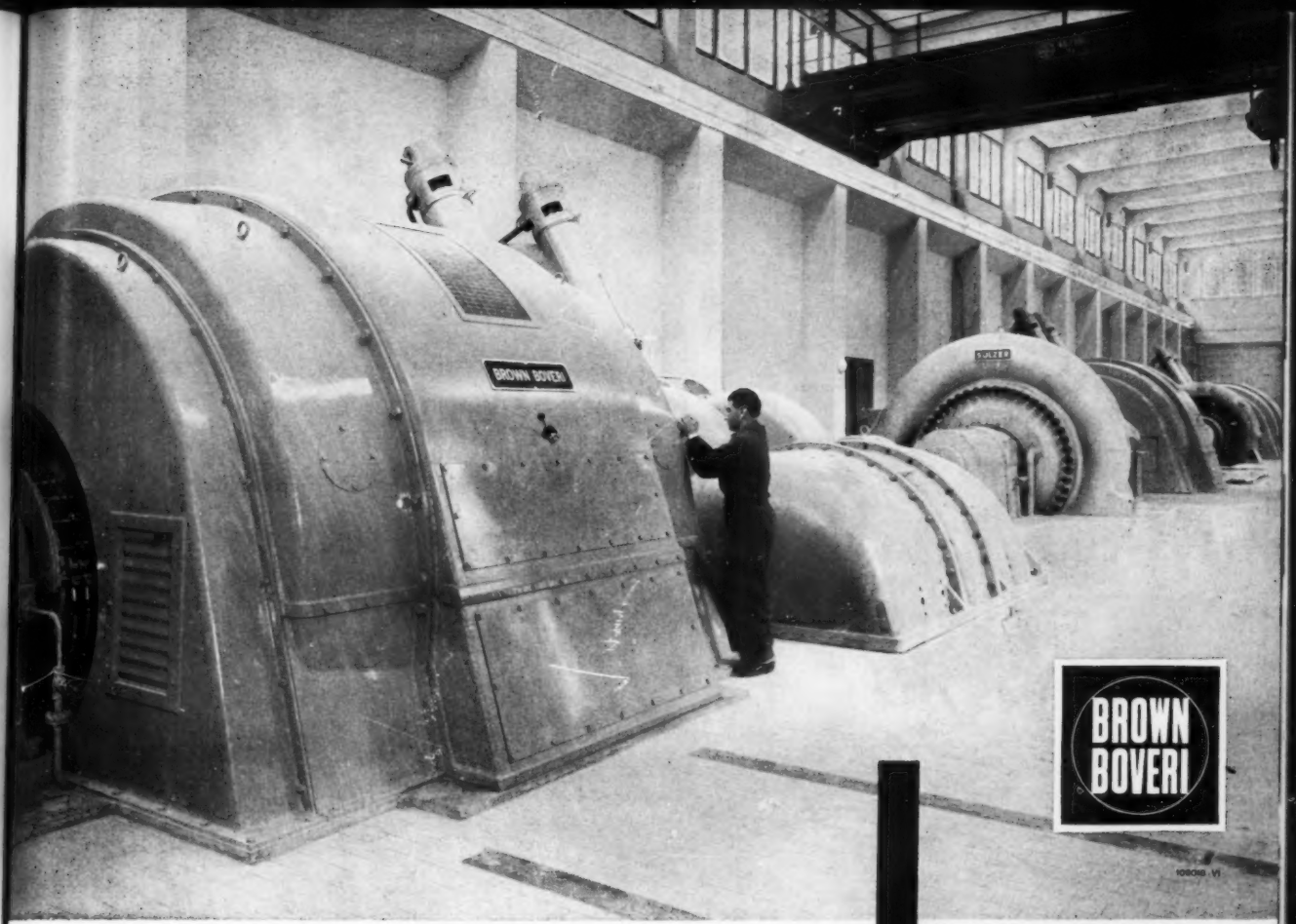

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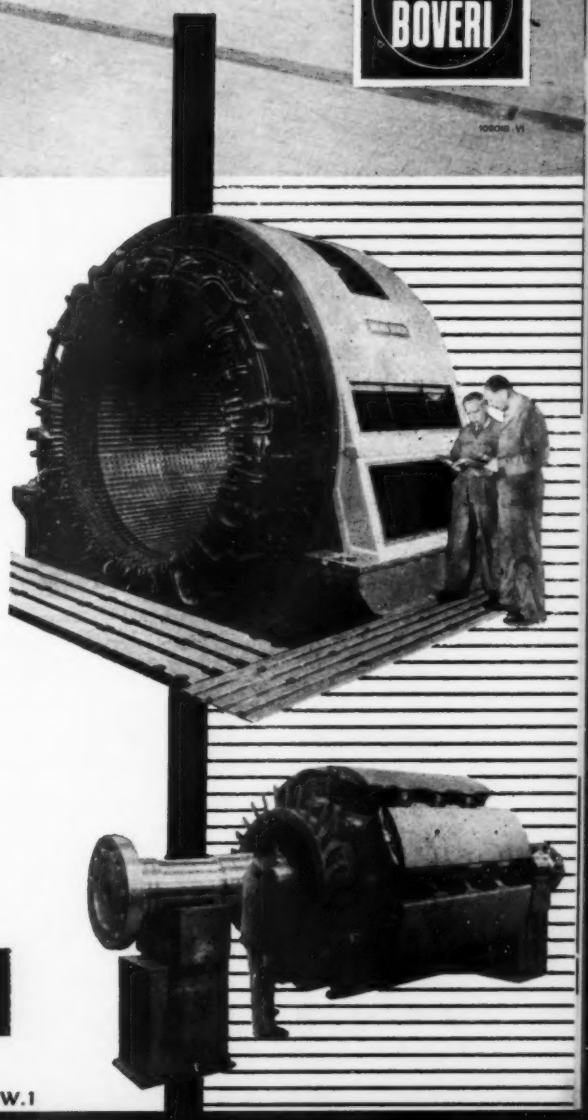

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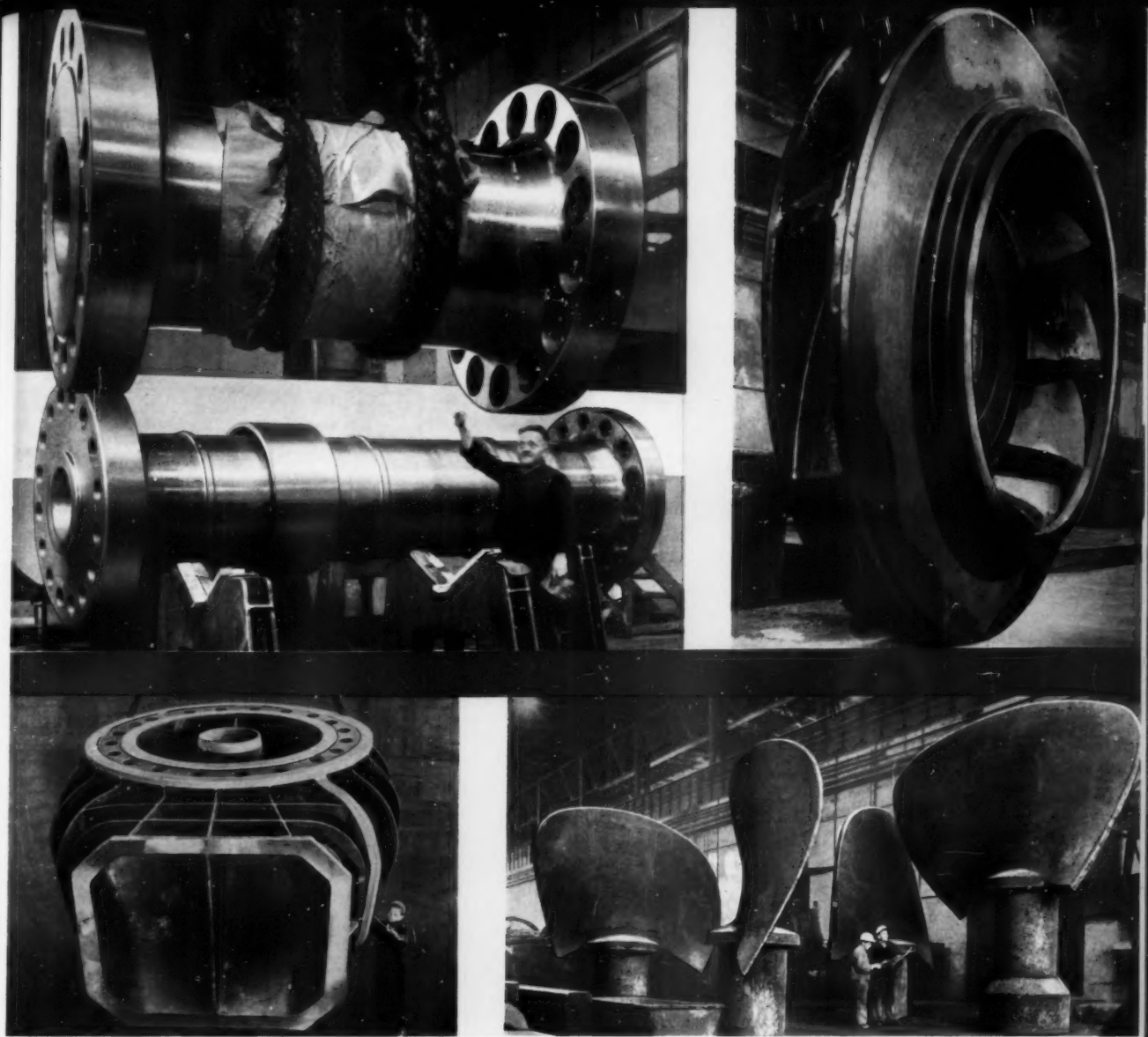

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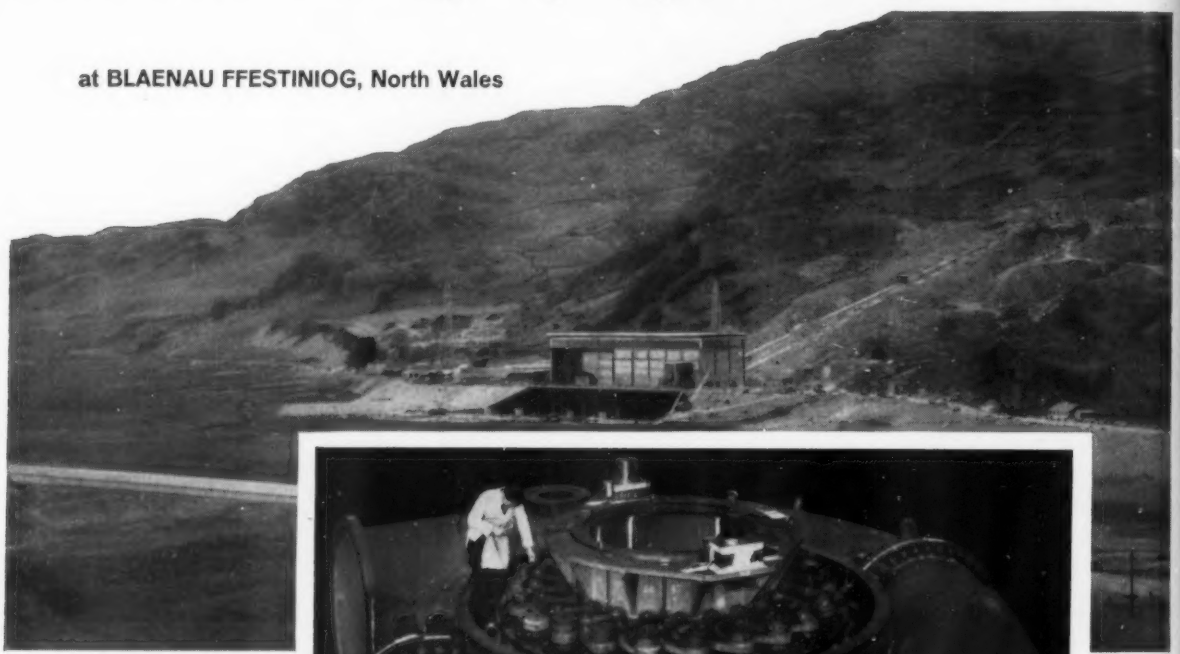

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